EP contribution to ARK VRZs 5-year review 2023

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Table of Contents

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Executive Summary

The ARK Commitment, established in 2018, included the implementation of VRZs to provide a buffer around penguin breeding colonies during the summer breeding season. An additional year-round VRZ was established in 2020 in one location. The Commitment is valid until 1 January 2024, with the possibility of a renewal for another 5-year period pending a review of the first 5-year period. This document presents the contribution of the ARK Commitment's Expert Panel (EP) to that review. The document includes the following sections, which are also summarized below (i) Governance and Procedures, (ii) Operational aspects, (iii) Status of krill predators, (iv) Progress in adopting a D1MPA. Further relevant information is available in the Annexes which provide a compliance report and additional details about the EP.

Summary – Governance and Procedures

The EP noted a lack of clarity about the purpose of the annual review process and the role of the EP itself. This compounds the lack of clarity about how the ARK Commitment contributes to the sated objectives of "improving sustainability" and "*a large-scale network of marine protected areas in the Antarctic Ocean*".

Key terms in the available description of the annual review process include "*improvements of ARK's Commitment to protecting krill dependent predators*" and *"improved sustainability of the krill fishery".* These terms are ambiguous and have no associated performance indicators against which improvement could be evaluated. More significantly there is no mechanism for modifying the ARK Commitment, including the VRZs, in response to feedback. This factor contributed to one member's resignation from the EP.

The EP noted that the RP's expectations of it often exceed the capacity of the EP to fulfill them. For example, the EP does not have the authority or resources to harmonize multiple conservation and management initiatives. This is an activity which is currently being organized by SC-CAMLR.

The EP recommends that documentation explaining the ARK Commitment and annual review process should be consolidated, simplified, and made consistent with the capacity of both the EP and the RP. The EP supported continuing engagement with the annual review process based on improved clarity about objectives and capacity, and more autonomy in identifying its own priorities.

Summary – Operational aspects

An analysis of the implementation of Best Commercial Effort (BCE) and the potential impact of VRZs on fishing operations was conducted by ARK's Executive Officer and reviewed by the EP. The BCE principle indicates that vessels should stay out of the VRZs all year round, unless catches are low elsewhere, to gain experience of the practicalities and potential impact on the commercial fishery of the VRZs. Analysis of the distribution of catches inside and outside VRZs indicates that the fleet reduced the use of the VRZs as fishing grounds from 2019 onwards. Before 2019, fishing in the areas that became VRZs occurred mainly during summer and late winter. After the implementation of the VRZs, the fishing fleet has generally avoided Subarea 48.1 in the early part of the fishing season, when pre-2019 catches were concentrated in coastal areas. Fishing in the areas which are now VRZs has also been reduced during the later part of the fishing season when seasonal VRZ restrictions do not apply, but the BCE principle does.

The establishment of the VRZs has not affected the fleet's capacity to catch the entire trigger level for Subarea 48.1, which it has done in most seasons from 2012/13 onwards. However, daily catch per vessel has declined since the introduction of the VRZs. There has also been a decrease in both the total number of fishing days per season and the total catch per vessel throughout the study period (2010-2022). Potential causes for the latter include changes in the composition and experience of the fishing fleet.

Although fishing within VRZs has been reduced, it has not been eliminated. Some of this fishing is in compliance with the VRZs (i.e. it occurs in seasonal VRZs during the open season). There is little evidence to suggest that this fishing is consistent with the BCE principle. That is, there is little evidence of lower-than-average catches or declining catch rates before vessels begin fishing in VRZs. Some of the fishing in VRZs does not comply with the ARK commitment. 143 tonnes of krill were caught in the year-round Hope Bay VRZ in 2022/23. The EP notes that the location of this VRZ was chosen by the RP, with the involvement of the fishing industry, and that there was little to no fishing in this area before the establishment of the VRZ. Thus fishing in that location has increased since the year-round VRZ was established.

The EP noted that it is inappropriate for the RP to ask the EP to assess the “cost” to the fishery of complying with the VRZs.

Summary – Krill predators

The EP reiterated its long-standing position that there are many potential drivers of change in krill predator populations including (i) changes in the availability of krill, (ii) changes in the availability of other prey and (iii) changes in other factors (such as predation of offspring) affecting the survival of the predators. Changes in the availability of krill could result from (i) changes in predation driven, for example, by increasing whale populations, (ii) changes in krill distribution or recruitment, or (iii) fishing. The EP can report on observed changes in predator populations, and scientific studies which attribute the cause, but it has not been provided with any data or resources to assess the influence of VRZs on these changes.

The ongoing population declines in two of the three pygoselid penguin species in Subarea 48.1 is likely to maintain public interest in conservation efforts to protect these species. While there is some evidence that these populations may be sensitive to the effects of krill fishing, there is no evidence that krill fishing is the sole driver of these declines. The collection of data on penguin populations was severely affected by the covid pandemic which began in the second fishing season after the VRZs were established; thus, there is limited data to explore whether the VRZs have helped to slow these declines.

Humpback and fin whales currently seem to be recovering in the WAP, although at different rates, whereas there may be a decline in minke whales. Subarea 48.1 encompasses hotspots for humpback whale, minke whale and fin whale foraging, with Humpback and minke whales using interior waters (Bransfield and Gerlache Strait) from summer until early winter, whereas fin whales prefer more offshore areas, off the South Shetland Islands (SSI) and Elephant Island, and may migrate earlier (April). Interannual variation in the reproductive rates of humpback whales along the WAP suggest that humpback whale populations may now be limited by krill availability, rather than there being a 'krill surplus'.

The Antarctic fur seal population at SSI has declined in the last two decades, mainly affected by leopard seal predation on pups. The local breeding population in SSI uses foraging areas beyond the VRZ. A larger population of breeding females use the WAP region mainly during fall and winter and have little to no overlap with the VRZs. Adult males occupy the WAP area (including the VRZs) between January and October in large numbers.

Summary – Progress in adopting a D1MPA

Since the implementation of the VRZs there has been no progress on adopting a Marine Protected Area in Domain 1 (Subareas 48.1 and 48.2).

Summary – Concluding remarks

The evidence to date suggests that the majority of ARK members have adapted their fishing behavior to comply with the seasonal VRZs when they are closed and minimize fishing in the seasonal VRZs during winter. Nonetheless 100% compliance has not been achieved and recent fishing in the year-round VRZ is a particular cause for concern.

The 5-year review process and analysis of BCE highlight the ongoing lack of clarity in the ARK Commitment and its implementation. There is a lack of shared understanding of the roles and objectives of the two panels and no evidence that fishing officers are adhering to BCE principles. Furthermore there is no mechanism for implementing improvements in response to the review process.

There is a responsibility under the current regulatory regime to ensure the conservation of all "harvested, dependent and related populations". The VRZs were intended to protect penguin breeding colonies, which may be an important contribution to this effort, but it is also important that any effort to protect penguins does not displace impacts disproportionately to other predators such as baleen whales. The ecological effects of the VRZs (positive or negative) are not currently known. This lack of knowledge is not evidence of a lack of impact, rather it is evidence of the lack of strategic monitoring and analysis that is necessary to detect or rule out impacts. There was a reduction in vessel catch rates after the VRZs were established, but there is insufficient evidence to attribute this to the VRZs. In the view of the EP, the VRZs are based on an untested hypothesis that they protect penguin colonies from negative impacts of fishing during the breeding season. On balance the EP supports the continuation of the VRZs, but emphasises the need to acquire evidence to test the hypothesis. An extension of the ARK Commitment would provide an opportunity to resolve some of the issues which have been identified during the review process, specifically the lack of clarity about objectives, the lack of a mechanism for improvement, the lack of an appropriate monitoring regime, and the lack of resource to support analysis. The RP could assist in this effort by identifying resources and supporting institutional efforts to manage research and monitoring to obtain better information.

1. Governance, Process and Procedures

Introduction

The Association of Responsible Krill Harvesting Companies (ARK) announced its commitment to implementing a set of Voluntary Restricted Zones (VRZs) around penguin colonies in the Antarctic Peninsula region (CCAMLR Subarea 48.1) in 2018. The document stating this commitment included provision for an "annual review of voluntary restricted zones". Subsequently, proponents of the VRZs established two panels to conduct these annual reviews:

(i) A Review Panel (RP), consisting of representatives of ARK-affiliated fishing companies and environmental non-governmental organizations (NGOs), with the stated goal "*to provide a yearly review and advice on the performance and need for improvements of ARK's Commitment to protecting krill-dependent predators*."

(ii) An Expert Panel (EP), consisting of ecosystem scientists, assisted by the ARK Executive Officer, tasked with the stated goal to "*provide a technical review and advice for improving ARK capacity to fulfill its commitment towards the improved sustainability of the krill fishery*".

Text Box 1 provides detail of the annual review process and the roles of the two panels in the form of verbatim quotes from relevant publicly available documents: The annual review process is described in the *ARK Commitment* document (2018) [1] and the *ARK Commitment Review Process* document [2] which also contains the RP and EP terms of reference. An updated statement of EP capabilities and contributions is provided in the EP's fourth annual report (2022) [3].

As part of the 5-year review of the VRZs in 2023, the EP was tasked with reporting on the VRZ review process' "*governance, process and procedures*" under the following headings:

a) Effectiveness of the annual review process
b) Effectiveness/fit for a scope of EP and RP composition
c) Transparency of [the] process to [the] public

The six current members of the EP met on 16th March and produced the following report.

Effectiveness of the annual review process

The EP considered whether the annual review process is fit for purpose. An important problem is that this purpose is not clearly defined.

The *ARK Commitment* document [1] identifies its scope as follows: "... *the companies have decided to make a number of commitments as part of improving sustainability as well as recognizing industry's role in contributing to the long-term ambition for a large-scale network of marine protected areas in the Antarctic Ocean.*"

These commitments are:

(1) Stepwise implementation of Voluntary Restricted Zones;

(2) Annual review of Voluntary Restricted Zones;
(3) Implementation of full year Voluntary Restricted Zones;
(4) Transshipment;
(5) Vessel safety.

- ***First interpretation of purpose: Completion of tasks listed in the ARK Commitment document.***

The text of the second commitment (*Annual review*) is quoted in **Text Box 1** (item 1). This lists three tasks that should be completed during the annual review. Thus, the "purpose" of the annual review process could be simply to complete these tasks.

- ***Second interpretation of purpose: Improvement of protection and/or sustainability.***

The Terms of Reference (ToRs) of both the RP and the EP (**Text Box 1,** items 2 & 3) state objectives in addition to the three tasks in **Text Box 1** (item 1), while the "goals" of both panels emphasize a requirement for advice on improvements. These goals could be interpreted as meaning that the purpose of the annual review process includes contributing to improvements in both protection of "*krill-dependent predators*" and "*sustainability of the krill fishery."* However, there is no mechanism for making improvements; rather, the Commitment only indicates that VRZs [1] are to be implemented from 1st January 2019, and then complied with them until either 2024 or 2029.

The EP also notes that the key terms "*protecting krill-dependent predators*" and "*improved sustainability of the krill fishery"* are ambiguous and have no associated performance indicators against which improvement could be evaluated.

A part of the purpose: A year-round VRZ.

The ToRs of both the EP and RP include reviewing the changes that are required to "*modify the seasonal VRZs into a year-round protection measure*". This relates to the commitment to designate a year-round VRZ in 2020. A year-round VRZ was agreed and designated within this timeframe. The RP asked for advice from the EP in identifying an appropriate site for a year-round VRZ. However, the RP rejected the advice provided by the EP and selected an alternative site. This demonstrates that the annual review process has been able to deliver a prior commitment. However, decision-making was not based on the evidence and advice provided by the EP.

The EP notes that the year-round VRZ did not affect fishing patterns (it closed an area with no prior fishing activity), and consequently, it had no immediate benefits in protecting predators. At the time that the year-round VRZ was designated, the RP noted that it "*would serve as a reference area to collect relevant information on Adélie penguins, and will require the establishment of an expert group to design appropriate data gathering and analysis*" [4]. This statement suggests an "improvement" with a tractable first step. The EP is not aware of any progress towards this improvement.

- ***Third interpretation of purpose: Objectives of the EP.***

The ToRs of the EP (**Text Box 1,** item 3) include objectives beyond the scope of the annual review tasks specified in the Commitment document (**Text Box 1,** item 1). These additional tasks are:

1. *Assess …the possible operational challenges in complying with the VRZ as a seasonal measure and the principle of "best commercial effort" outside of the seasonal measure*.
2. *Review the required changes to modify the seasonal VRZs into a year-round protection measure and the size of such protection*.

3. *Harmonize current voluntary measures with other initiatives discussed in CCAMLR (i.e., D1MPA, FBM, CM 51-07).*
4. *Provide advice on complementary, operable industry measures to provide adequate ecosystem protection while waiting for equivalent CCAMLR regulations to be adopted.*

The second task ("*required changes to modify the seasonal VRZs into a year-round protection measure*") has been completed and is discussed above. Although this task is not included in the annual review task, the ARK Commitment document is clear that "Implementation of full year VRZs" should be based on the annual review.

The EP has provided feedback in its Annual Reports to the RP on the above tasks. In general, tasks 1, 3 and 4 are beyond the current capacity of the EP. Furthermore, the view of the EP is that it is not responsible for assessing "operational challenges" on behalf of the fishing industry. The EP has therefore provided a statement of its capabilities and expected contribution to the review process (**Text Box 1,** item 4).

<u>Evaluation of annual review process against three interpretations of purpose.</u>

- ***First interpretation of purpose***

The annual review process is adequate to complete the three original tasks specified in the Commitment document (**Text Box 1**, Item 1). The first task ("*Review the catch inside and immediately outside the voluntary restricted zones"*) is made difficult by the refusal of some ARK affiliated fishing companies to supply catch data, but the EP has been able to obtain proxy data from other sources.

- ***Second interpretation of purpose***

The annual review process is not fit for the purpose of helping to improve the VRZs for added protection of krill dependent predators, or sustainability of the krill fishery, as there is no mechanism for implementing improvements after 2019.

- ***Third interpretation of purpose***

Furthermore, the annual review process is not fit for the purpose of fulfilling all of the objectives stated in the EP ToRs. The EP has attempted to remedy this situation by providing a modified statement of its capabilities and expected contributions (**Text Box 1**, Item 4). The annual review process is adequate to deliver these contributions.

The EP discussed its relationship with the RP. The RP seems uncertain about the role of the EP and, in most years, has made requests to the EP that are not consistent with the capacity of the EP. These requests generally concern identifying the "conservation benefits" of the VRZs or assessing the operational implications for the fishing industry. The EP provided an updated statement of its capabilities and contribution in its fourth annual report (2022) [3] but the subsequent RP report (paragraph 7 of the section "Outcomes of the Expert Panel 2022 Report" in the RP report 2022 [4]) suggests that this was either not read or not understood. Thus, the main available route of communication between the EP and the RP (the annual report) seems to be ineffective in that respect.

The EP discussed the support it receives to do its work. The ARK executive officer serves as secretary to the EP and conducts the analysis to fulfill the first task (“*Review the catch inside and immediately outside the voluntary restricted zones”*) in the annual review process (Item 1 of **Text Box 1**)**.** This task also requires the provision of data. The EP reiterates that the refusal of some ARK-affiliated fishing companies to supply catch data is problematic, but also acknowledges the support of ARK in providing access to alternative proxy data.

The EP does not receive any further support from ARK or the other organizations represented on the RP. This is a critical factor limiting the capacity of the EP and therefore the scope of the annual review process. In particular, the EP does not have the capacity to deliver most of the objectives in its ToRs that are beyond the scope of the tasks specified in the Commitment document. Nonetheless the current level of support is adequate for the EP to deliver its contribution to the tasks listed in the Commitment document ([1], **Text Box 1,** item 1) and in its modified statement of capacity and expected contributions ([3] **Text Box 1,** item 4).

Effectiveness/fit for a scope of EP composition

The EP considered if the panel’s own composition is appropriate to fulfill its tasks. There has been a high turn-over of EP members in the last two years: Four members have left (three resignations and one death) since the 2021 report and four have joined (two of whom subsequently left). One resignation was partly due to a perception that the VRZs and the review process are a “greenwashing” initiative. Up to April 2023, the average period of panel membership was 2.45 years (excluding the member who passed away, but including three members who joined the panel when it was formed).

The first task in the annual review process (Item 1 of **Text Box 1**) is to “*Review the catch inside and immediately outside the voluntary restricted zones”.* This requires data processing and analysis, which is currently provided by the ARK executive officer, working with the EP chair. This is appropriate to deliver the task.

The second task in the annual review process is “*Review of new science, such as biomass survey and other relevant data and science.”* All members of the EP have a PhD-level scientific background. They include one ARK representative, one NGO representative, two marine mammal specialists, one penguin specialist and one krill specialist. The EP has the capability of reviewing a broad suite of relevant information, but does not include specialist knowledge on biomass survey (the only specific subject area identified in the task). Nonetheless, there is a clear imbalance between specialisms and a lack of coverage of other ecosystem components (notably fish). There is also an unequal spread of workload: the krill specialist is also required to contribute to the other two tasks, which contributes to further imbalance.

Some members of the EP felt that the inclusion of whale experts indicates a requirement for the EP to report on the implications of the VRZs for whales. The EP notes that the VRZs were developed as buffer zones around penguin colonies. There is a tension between the protection of penguins and whales, as the latter are more likely to feed in locations which remain open to fishing. However, the risk to either group of animals cannot be assessed without further research effort. The annual review process, as it currently stands, cannot answer questions which require further research effort.

The third task in the annual review process is *Feedback from expert- and scientific committees in CCAMLR*, specifically with respect to the Western Antarctic Peninsula MPA proposal (D1MPA). The

EP has taken a broader view of this task and reported more broadly on developments in krill fishery management. The EP now includes two active participants in CCAMLR working groups and one additional member who attends Scientific Committee meetings with observer status. This is appropriate to deliver the task and should be maintained.

The founding members of the EP were appointed by the EP. The EP then took a lead in appointing its own members. In its 2022 report the EP stated that "Replacement members will be selected by serving members of the EP when necessary." However, following this the RP appointed a new member to the EP without consulting the EP. This lack of independence from the RP limits the credibility of the review process.

The EP member who resigned in 2023 provided a detailed explanation, highlighting the "the limited scope and focus of the Commitment" and of the EP, continuing "I do not have the feeling that our expertise is sought to improve measures, or even to design measures most appropriate, but solely to legitimise the voluntary measure." The EP notes that there have been no improvements in response to its suggestions, and that the RP has rejected advice that it had solicited from the EP. Furthermore there is no mechanism for making improvements to the Commitment or VRZs based on the annual review process.

All current members of the EP are male, white and established in their careers. There is a clear lack of gender, ethnic and career-stage diversity in the panel.

Transparency of the process to the public

The EP has made its reports publicly available and notes that RP reports are also publicly available. These reports provide some transparency to interested parties but is unlikely that they will be widely read.

The lack of clarity about the purpose of the annual review process (indicated, amongst other things, by the RP's misunderstanding of the EP's capacity) will reduce the transparency of the process and therefore, public understanding of the purpose and effectiveness of the VRZs.

Summary

The current situation is that:

- (i) The specific purpose of the annual review process is unclear.
- (ii) There is an ongoing lack of clarity about expectations of the EP from the RP.
- (iii) The EP is able to contribute to the three basic tasks listed in Item 1 of **Text Box 1**.
- (iv) The EP is able to contribute to objective 1 of the EP ToRs (Item 3, **Text Box 1**) to the extent of assessing ARK member compliance with the VRZs, but not "operational challenges" or "best commercial effort".
- (v) The EP is able to contribute to objective 2 of the EP ToRs (reporting on penguin population trends).
- (vi) The EP has contributed to objective 3 of the EP ToRs (providing advice on year round VRZs).
- (vii) The EP considers that objective 4 of the EP ToRs (harmonizing various conservation and management initiatives) is beyond its current capacity.

(viii) The EP may be able to contribute to objective 5 of the EP ToRs (providing advice on complementary measures), subject to the caveat that the ability to provide advice is constrained by the limited capacity of the panel.
(ix) The composition of the EP lacks diversity and is weighted towards specialist knowledge of krill predators.
(x) The annual exchange of reports is transparent to the public but probably not widely noticed.

Members of the EP support continued engagement with the annual review process based on improved clarity about objectives, expectations and capacity. The EP also intends to take a more active role in identifying its own priorities. This is consistent with the EP's earlier offer to "*Provide additional information or advice which the EP considers relevant to the work of the RP*" (Item 4, **Text Box 1**).

Thus, we recommend that:

(i) The EP should continue to report annually, delivering the contributions stated in Item 4 of **Text Box 1**.
(ii) The EP should emphasize the provision of advice that it considers is relevant to the work of the RP.
(iii) If appropriate resources are provided, the EP should facilitate the delivery of occasional additional reporting on topics of interest, such as the relative effects of the VRZs on penguins and baleen whales.
(iv) The RP should advise the EP on appropriate steps to improve diversity and provide a more balanced spread of skills within its members.
(v) The documentation (setting out the rationale and purpose of the VRZs, the review process and the roles of the EP and RP) should be consolidated, simplified and made clearer and more consistent with the capacity of both panels.
(vi) Communication between the RP and EP should be based on a shared understanding of the roles of each.
(vii) The RP should consider other opportunities to raise awareness of the VRZs and the review process. For example, via AWR/CCAMLR funded whale observers on cruise ships.

Text box 1: Available written statements about the annual review process and the roles of the Review Panel and Expert Panel quoted from the documents in the reference list below.

Item 1: Description of the annual review process provided in the ARK Commitment document (2018) [1]

The signatories will review implementation of voluntary restricted zones annually, with the first review to be complete by the end of 2019. The annual review shall include:

a. **Viability for fishery**

Review the catch inside and immediately outside the voluntary restricted zones and share key findings with environmental NGOs and scientists who have expertise relating to the krill fishery and the CCAMLR Domain 1 planning process. This will be an independent review and participation in the review process shall be discussed with stakeholders and agreed to by the signatories to this Commitment.

b. **New Science**

Review of new science, such as biomass survey and other relevant data and science.

c. **Feedback from expert- and scientific committees in CCAMLR**

Evaluation of the formal expert/scientific process of the Western Antarctic Peninsula proposal (D1MPA). Such as the Scientific Committee in CCAMLR and its working groups.

Item 2: Review Panel terms of reference provided in the Commitment Annual Review document [2]

Mission

Provide advice to ARK on options to improve the principles and objectives of the ARK Commitment towards improved sustainability in krill fishing activity.

Goal

To provide a yearly review and advice on the performance and need for improvements of ARK's Commitment to protecting krill-dependant predators.

Objectives

1. Review the compliance to the VRZs, based on the outcome from the Expert Panel.
2. Review the required changes to modify the seasonal VRZs into a year-round protection measure.
3. Review the harmonization of the current voluntary measures with the development of theD1MPA and related initiatives discussed in CCAMLR (i.e., FBM, CM 51-07).
4. Review efforts and progress on achieving a network of MPAs and improved the ecosystem-based management of the krill fishery, by ARK and other stakeholders.
5. Review progress on best practices for ransshipments and how ARK can be of assistance to CCAMLR in the development of transshipment regulations.
6. Propose possible changes to the current ARK's Commitment guidelines for the coming fishing season.

Outcome

A Report to be submitted to the ARK AGM.

Annual Meeting and Members integrating the Review Panel 2019

Meeting date: the Review Panel will meet every year during the regular SC-CAMLR meeting at Hobart.

Item 3: Expert Panel terms of reference provided in the Commitment Annual Review document [2]

Mission

Provide an objective assessment of the performance and compliance of the krill fishery regarding the implementation of ARK's Commitment, as well as an update on penguin populations performance.

Goal

Provide a technical review and advice for improving ARK capacity to fulfill its Commitment towards the improved sustainability of the krill fishery.

Objectives

1. Assess the compliance with the Voluntary Restricted Zones (VRZ) by ARK's fishing vessels, herein the possible operational challenges in complying with the VRZ as a seasonal measure and the principle of "best commercial effort" outside of the seasonal measure.
2. Provide an update on penguin 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.

Item 4: The Expert Panel's statement of the ways it can contribute to the annual review process provided in the EP Annual Report 2022 [3]

The EP is able to contribute to the annual review process in the following ways:
(1) Analyse catch data to assess compliance with the VRZs.
(2) Report briefly on new data and research on the status of Antarctic krill and its predators in Subareas 48.1 and 48.2.
(3) Report briefly on developments in krill fishery management and ecosystem protection affecting Subareas 48.1 and 48.2.
(4) Provide expert opinion in response to clear requests from the RP.
(5) Provide advice on how the RP can progress its objectives when these are beyond the current capacity of the EP.
(6) Provide additional information or advice which the EP considers relevant to the work of the RP

Links to referenced documents

[1] ARK Commitment document (2018)
[2] ARK Commitment Annual Review document (2023)
[3] EP Annual Report 2022
[4] RP Annual Report 2020

2. Operational analysis

Scope of the Report

The "Operational Analysis" section of the report will focus on the Commitment objectives on (i) implementing Best Commercial Effort and (ii) reviewing the viability for the fishery of the implementation of VRZs.

In addition, the Review Panel considered it relevant to assess the following aspects regarding fishing operations:

- Development and implementation of best practices
  - i. Avoiding direct competition with central-place foragers (i.e., breeding penguins)
  - ii. Fishing strategy (location/time of fishing) and possible displacement as a consequence of the implementation of seasonal closures and "Best commercial effort."
- Cost for the industry
  - Cost for the industry in terms of catch loss or reduced fishing opportunities

Approach

Best practices and impact on fishing performance were assessed through a comparative analysis of changes at the fleet and vessel level, before and since the implementation of VRZs. Several metrics were used, including catches, fishing effort, and distance traveled.

Implementation of Best Commercial effort

The Best Commercial Effort indicates that vessels should "…stay out of the voluntary restricted zones […] all year already in 2019, to gain experience of the practicalities and potential impact on the commercial fishery of implementing the voluntary restricted zones as a full year measure." The commitment acknowledges the likelihood of encountering resistance and potential impacts on fishing patterns upon closing areas to fishing. However, by enacting voluntary measures, the commitment aims to facilitate the integration of the concept into daily operations and the evaluation of actual effects on fishing performance. The Best Commercial Effort (BCE) guideline was reviewed by ARK in December 2019 (see Annex 1) and has remained in place since. There are two components to the BCE:

- Fishing effort: targeting krill inside VRZs should be reduced
- Fishing behavior: vessels should fish within VRZs only after scouting surrounding areas and finding fishing performance to be insufficient.

Accordingly, the analysis of BCE was conducted by–

- Comparing the use of VRZ areas in the periods 2010 to 2018 and 2019 to 2022 after the seasonal closure is lifted (at the end of February), in terms of fishing effort (number of hauls and fishing days) and catches (monthly and seasonal). The expectation is that the proportion of catches inside VRZs, from March onwards, has decreased since the implementation of the ARK Commitment.
- Analyzing the behavior of fishing vessels just before entering a VRZ, to evaluate if they had fished in the vicinity of the VRZ before entering into it. The expectation is that fishing performance in the vicinity of a VRZ in the days preceding an entry into a VRZ should be

lower in comparison with (i) the mean catches for that month, and (ii) mean catches inside the VRZ in the following days.

Cost for the industry

Implementation of the VRZs could have negative effects on fishing operations in terms of catch loss or reduced fishing opportunities. In particular, potential risks from the implementation of VRZs include –

- reduction in total catches
- reduction in catch performance resulting from:
    - increased fishing effort, due to inability to access preferred fishing grounds
    - increased search time, by forcing vessels to look for new fishing grounds or move more frequently between smaller krill patches
    - reduced CPUE, due to the displacement towards areas with less favorable krill patches.

Accordingly, the potential impact of VRZs on fishing operations was assessed by comparing fishing effort (no. hauls and fishing days), CPUE (return by fishing effort), overall catches (monthly and seasonal) and distance traveled across seasons.

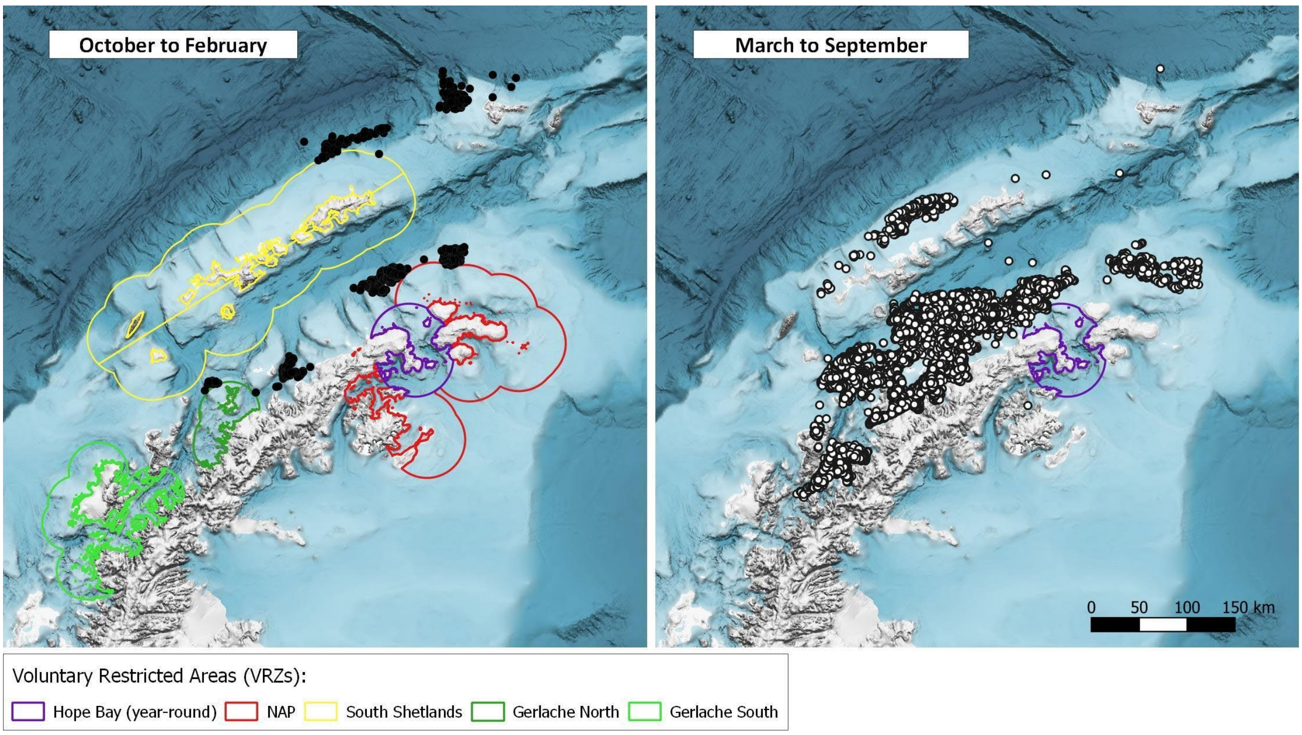

Figure 1. Fishing grounds in Subarea 48.1, depicting the VRZs and tow positions for fishing seasons 2018/19 – 2021/22. Left: seasonal VRZ active (October-February), Right: seasonal VRZ lifted (March-September).

Methods

Data Availability

Analyses were conducted for seasons 2010/2011 – 2021/2022 using haul-by-haul data provided to the ARK database by four ARK members, accounting for seven of the eleven ARK-affiliated vessels that fished in this period (Figure 2). Seasons are referred to by the year they end (i.e., season 2012/13 = 2013). Data was imported from Excel sheets, and a preliminary cleaning was performed as follows: data with no catches were removed; hauls positions were filtered and corrected when obvious (i.e., -420.6 instead of -42.06), using positions for the preceding/following three hauls; date mistakes were corrected when obvious. Clean data was processed as follows: haul distribution was estimated as the middle point between the start and end of each tow; distance between hauls was estimated, and then data was filtered for speed estimates above 15 knots. Catches below 100 kg were eliminated, as they may correspond to survey tows.

Best Commercial Effort, BCE

BCE was assessed for Subarea 48.1 by comparing two alternative methods. First, the proportion of catches inside/outside VRZ after the seasonal protection is lifted (March-July) was compared for the period 2010-2018 (before VRZs) and 2019-2022 (with VRZs in place). Fishing effort was estimated as the proportion of catches (Catch_out), tows (Tows_out) and fishing days (Days_out) outside VRZs, and fitted using a generalized linear model (GLM) with a binomial distribution, *glm*: Catch_out ~ predictors, family = binomial(link = "logit"). Fishing effort was modeled considering the following predictors: *vessel*, *year*, *month*, *VRZ period*. Under BCE, the proportion of catches outside VRZs should increase from 2019 onwards after accounting for other variables (e.g., vessel, month).

In a second analysis, we compared fishing performance on the days immediately before and after entering a VRZ, for both periods indicated above. Fishing performance, measured as CPUE1 = ton per tow, and CPUE2 = ton per day, were estimated for the 5 days before, and 5 days after the date that a vessel makes the first tow inside a VRZ. As vessels sometimes enter and exit a VRZ frequently, e.g. when fishing near the border, events were grouped if the entry/exit occurred within 4 days. Under BCE a vessel should enter a VRZ only when the CPUE outside the VRZ (i) is lower than the monthly average CPUE, or (ii) has a negative trend (indicating a reduction in catches). There may be cases when there is a reasonable expectation that the CPUE will be higher inside the VRZ, which would be verified by (iii) an increase in CPUE on entering the VRZ. In order to detect such effects it is necessary to account for the influence of other variables (e.g., vessel, month).

CPUEs for contrasting cases were compared using paired t-test on the difference between (i) month and (ii) VRZ minus CPUE outside VRZ. Similarly, the average slope of CPUE before entering a VRZ was tested for mean < 0 using a t-test. Additionally, the slope of the CPUE before entering the VRZ were analyzed through a GLM with gaussian distribution, *glm*: slope ~ predictors, family = gaussian. Predictors considered were *vessel*, no. of tows (*no.tow*), no. of fishing days (*no.days*), year (*season*), *VRZ period*. Under BCE, the CPUE slope should decrease before entering the VRZ.

Operational Costs

Operational costs associated with the implementation of the VRZs were assessed by comparing fishing effort (no. hauls and fishing days), CPUE (return by fishing effort), and overall catches (monthly and seasonal) across seasons. However, the database used is incomplete and unbalanced, with many more vessels affiliated with ARK in 2020 than in 2010 (ARK was founded in 2012). Accordingly, analyses were performed using *vessel* as the basic unit, and comparing changes in performance for each *vessel* over the period analyzed.

The database was filtered to include only vessels that had fished at least two seasons before and during the ARK Commitment period. The database was further restricted to December-July, as data are scarce for other months. On the other hand, fishing performance could change if the fleet size changes, thus we also included the number of fishing vessels active that season (fleet size).

Accordingly, we log-transformed the CPUE and then fitted them using a GLM with a gaussian distribution, *glm*: log(CPUE +1) ~ predictors , family = gaussian. We used three CPUE indices: CPUE1 = ton/tow, CPUE2 = ton/day, and CPUE3 = average ton/day on a monthly basis. CPUE was modeled considering the following predictors: *vessel*, *year*, *month*, *VRZ period*, inside/outside VRZ (*VRZ_in*), *fishing method*, and fleet size (*No.Ships*). Additionally, we compared the total catch obtained by amount of effort, measured as the number of fishing days and distance traveled, for the period before and after the implementation of the VRZs. Data from vessels with less than 10 fishing days in a given season were excluded from the analysis. Fishing effort and catches were modeled using a glm with a Gaussian family, with the following predictors: *vessel*, *season*, *VRZ period*, *fishing method*, and fleet size (*No.Ships*). We would expect the CPUE or the total catch to be reduced from 2019 onwards, or the distance traveled to increase, after accounting for other variables (e.g., vessel, month), if the VRZs have an impact on fishing performance.

Data Analysis

Model performance was evaluated using BIC and AIC criteria, in that order. BIC was considered the primary index, considering the different levels of freedom between predictors. Model selection followed a manual forward stepwise process, with each predictor modeled independently; the best predictor was selected and then added to the next stepwise round. The process concluded when no more predictors were left, or BIC/AIC increased again. Models with BIC/AIC differences <2 were considered as having a similar fit, and compared using *anova*.

All analyses were run in R 4.2.2 (R Core Team 2022) under RStudio 2023.03.1 GNU. Packages used for analyses included the following: data manipulation: 'readr', 'openxlsx', 'dplyr', tidyverse', 'lubridate', 'reshape'; spatial analysis: 'sf', 'raster', 'units'; visualization: 'ggplot2', 'ggformula', 'gghalves', 'tmap'.

Spatial analyses were conducted using the South Pole Lambert Azimuthal Equal Area Projection, centered at longitude 50°W.

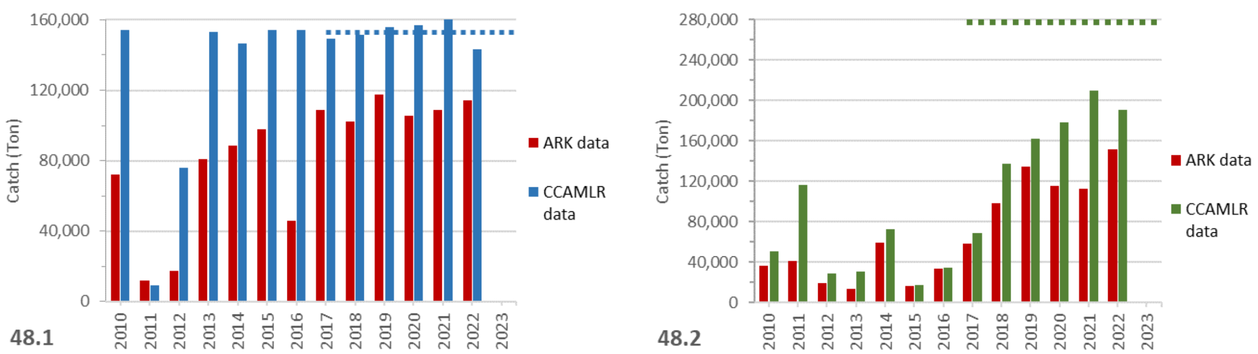

Figure 2. Total catches available in ARK database, in comparison with total catches recorded by CCAMLR, for Subareas 48.1 (*left*) and 48.2 (*right*).

Results

Best Commercial Effort

We analyzed the proportion of catches and fishing effort performed inside and outside VRZs, for the period before and after the implementation of the ARK Commitment using a Generalized Linear Model (GLM). The BCE principle calls for a reduction in fishing effort (and catches) inside VRZs even after the seasonal prohibition has been lifted. GLM models for catches, number of tows and fishing days all selected the same set of variables, thus here we only present results for the proportion of catches inside VRZs (*Catch_IN*). The best GLM model identified *Month* and the interaction of *Month:VRZ* as the most important predictors explaining catch distributions (Table 1). After accounting for Month, the establishment of the VRZs reduced the proportion of catches inside the VRZs (Month:VRZ_YES: coeff = -0.124, SE = 0.068, p = 0.068) for the period between March and July (Fig. 3).

We also tested for changes in fishing performance (CPUE) and effort (no. tows or days) before and after entering a VRZ, under the assumption that inside the VRZ the performance would be greater, leading to higher fishing effort. This analysis focuses on periods when fishing occurred close to VRZs and before entry. Fishing efforts initiated within a VRZ without prior scouting were not considered. The paired t-tests indicated that both CPUE1 (ton/tow; diff = -1.644, p =0.006) and the number of tows (diff = -12.79, p =0.002) were lower after entering a VRZ during the BCE period, suggesting that catches inside the VRZ were not better and that vessels did fewer tows than the previous 5 days (Table 2). Likewise, CPUE2 (ton/day; diff = -1.998, p =0.011) was also lower after entering the VRZ compared to the previous 5 days.

Likewise, the difference between CPUE1 and CPUE2 with respect to the average for that month indicates that the CPUE was lower in the 5 days after entering a VRZ than the monthly average, for the whole study period (with and without the implementation of BCE; Fig. 4).

We also analyzed for a potential decline in CPUE during the 5 days before entering a VRZ as a factor in explaining the entry to a VRZ. Results indicated that the slope for CPUE1 and CPUE2 were both non significantly different from 0 (Table 3a), with the introduction of BCE having no significant effect on CPUE2 (Table 3e-f), and only a marginal effect on CPUE1 (VRZ_periodYES: coef = 0.081, SE = 0.048, *p* = 0.095, Table 3d).

Table 1. GLM analysis of factors affecting the proportion of catches and fishing effort in/out VRZs.

A. Monthly Analysis –glm(Formula, family = binomial(link = "logit"))

Formula	Deviance explained	Chi.sq	DF	*p*(Chi.sq)	AIC value	BIC value
Catch_IN ~ VRZ	2.2%	3.11	1	0.048	227.56	234.16
Catch_IN ~ VRZ + Month	5.3%	7.37	2	0.013	225.23	235.13
Catch_IN ~ VRZ + Month + Year	6.8%	9.54	3	0.010	226.35	239.54
Catch_IN ~ VRZ + Month + Year + Fish_method	6.9%	9.57	4	0.020	228.24	244.73

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1'' 1

Month : 3,4,5,6,7
VRZ : VRZ_NO = 2010-2018; VRZ_YES = 2019-2022
Year : 2010-2022
Fish_method: traditional / continuous pumping

B. Model comparison using rcompanion::compareGLM

Mod #	Formula: Catch_IN ~	Rank	AICc value	AIC weight	BIC value
1	VRZ	2	229.7	0.0526	239.5
2	VRZ + Month	3	227.4	0.1662	240.4
3	VRZ + Month + Year	4	228.7	0.0868	244.8
4	VRZ + Month + Year + Fish_method	5	230.7	0.0319	250
5	Month + VRZ	3	227.4	0.1662	240.4
7	Month + Month:VRZ	3	226.8	0.2243	239.7

C. Summary of model 7

```
glm(formula = Catch_IN ~ Month + Month:VRZ, family = binomial(link = "logit"), data
= BCE.month)

Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)  -2.19108    0.67427  -3.250  0.00116 **
Month         0.33343    0.14153   2.356  0.01848 *
Month:VRZYES -0.12395    0.06784  -1.827  0.06769 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 139.36  on 199  degrees of freedom
Residual deviance: 131.40  on 197  degrees of freedom
AIC: 224.55

Number of Fisher Scoring iterations: 3
```

Table 2. Paired t-test on fishing effort and CPUE between the 5 days before and after entering a VRZ. CPUE1 = ton/tow; CPUE2 = ton/day.

Expected results:

(i) CPUE is lower before entering a VRZ: CPUE(after – before) > 0
(ii) Fishing effort is lower before entering a VRZ: Effort(after – before) > 0
(iii) CPUE is lower before entering a VRZ than the monthly average: CPUE(month – before) > 0
(iv) CPUE is higher after entering a VRZ than the monthly average: CPUE(month – after) < 0

Grayed-out: significant results in agreement with the expected results.
Red letters: significant results but opposite to the expected results.

	Comparison	VRZ/ BCE period	Mean (diff)	SD (diff)	N	*t* value	*p*(t)
CPUE1	(after – before)	NO	*0.530*	9.358	121	0.623	0.534
	(after – before)	YES	-1.644	6.294	117	-2.825	0.006 **
Fishing effort (No. tows)	(after – before)	NO	-1.508	50.604	126	-0.334	0.739
	(after – before)	YES	-12.790	44.774	124	-3.181	0.002 **
CPUE2	(after – before)	NO	*0.246*	8.673	121	0.312	0.756
	(after – before)	YES	-1.998	8.311	117	-2.600	0.011 *
CPUE1	(month- before)	NO	*1.542*	6.322	121	-2.684	0.008 **
	(month- before)	YES	-0.408	4.964	117	0.890	0.376
	(month - after)	NO	1.012	5.497	121	-2.025	0.045 *
	(month - after)	YES	1.235	4.700	117	-2.843	0.005 **
CPUE2	(month- before)	NO	*1.274*	6.011	121	-2.331	0.021 *
	(month- before)	YES	-0.515	6.139	117	0.907	0.366
	(month - after)	NO	1.028	5.557	121	-2.035	0.044 *
	(month - after)	YES	1.483	4.962	117	-3.234	0.002 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Table 3. Analysis of CPUE slope for the 5 days before entering a VRZ.

A. Test for mean < 0

	VRZ period	mean slope	SD slope	N	t value	p-value
CPUE1	NO	-0.002	0.039	92	-0.056	0.478
	YES	0.042	0.024	97	1.740	0.957
CPUE2	NO	0.115	0.476	79	0.242	0.595
	YES	0.042	0.024	87	1.740	0.957

B. GLM: CPUE 1 slope ~ .

Model #	Predictors	Deviance explained	Chi.sq	DF	*p*(Chi.sq)	AIC value	BIC value
1	~ no.tow	1.1%	0.198	1	0.813	97.813	107.538
2	~ no.tow+ VRZ_period	1.5%	0.278	2	0.435	98.962	111.929
3	~ no.tow + VRZ_period + Vessel	9.1%	1.648	8	0.02	95.927	128.344
4	~ no.tow + VRZ_period + Vessel + Season	13.8%	2.512	18	0	105.787	170.622

C. ANOVA comparison of the two best models

Analysis of Deviance Table: anova(model 1, model 3, test = "Chisq")

Model #	Resid. Df	Resid. Dev	Df	Deviance	Pr(>Chi)
1	187	17.987			
3	180	16.537	7	1.450	0.027 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1'' 1

D. Best model for CPUE1:

Call:glm(formula = slope ~ no.tow + VRZ_period + Vessel, family = gaussian, data = CPUE1_slope)

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	-0.034	0.086	-0.392	0.696
no.tow	-0.002	0.001	-2.586	0.010*
VRZ_periodYES	0.081	0.048	1.678	0.095.
Vessel-1	-0.015	0.132	-0.117	0.907
Vessel-2	0.269	0.102	2.630	0.009**
Vessel-3	0.099	0.097	1.018	0.310
Vessel-4	0.044	0.095	0.464	0.643
Vessel-5	0.191	0.101	1.879	0.062.
Vessel-6	0.030	0.093	0.320	0.749

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Null deviance: 18.185 on 188 degrees of freedom
Residual deviance: 16.537 on 180 degrees of freedom
AIC: 95.927
Number of Fisher Scoring iterations: 2

E. GLM: CPUE 2 slope ~ .

Predictors	Deviance explained	Chi.sq	DF	*p*(Chi.sq)	AIC value	BIC value
no.days	0.2%	5.658	1	0.01	984.481	993.817
no.days + VRZ_period	0.3%	8.855	2	0.006	986.331	998.779
no.days + VRZ_period + Vessel	2.9%	104.165	8	0	993.781	1024.9
no.days + VRZ_period + Vessel + Season	8.0%	283.998	18	0	1004.84	1067.08

F. Best model for CPUE2:

Call:glm(formula = slope ~ no.days, family = gaussian, data = CPUE2_slope)

Deviance Residuals:

Min	1Q	Median	3Q	Max
-22.5699	-1.2608	-0.1252	0.8794	29.4332

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.8736	1.2205	0.716	0.475
no.days	-0.1381	0.2692	-0.513	0.609

Null deviance: 3534.0 on 165 degrees of freedom
Residual deviance: 3528.3 on 164 degrees of freedom
AIC: 984.48
Number of Fisher Scoring iterations: 2

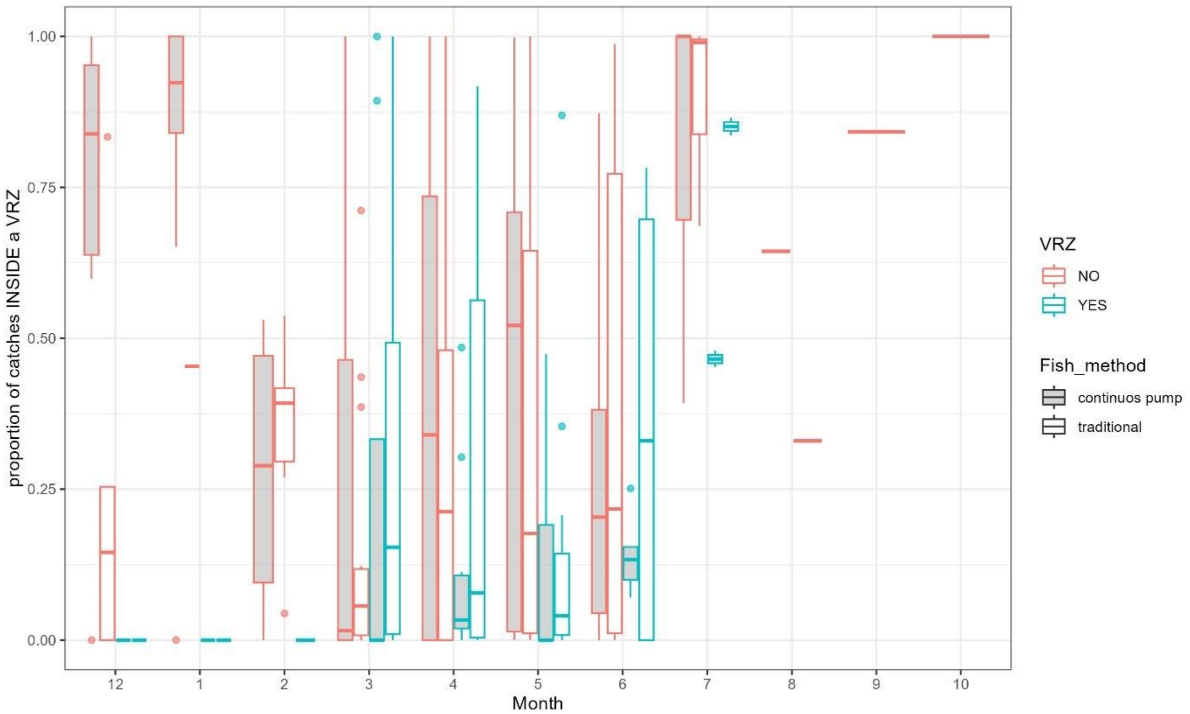

Figure 3. Proportion of catches fished inside VRZs for the study period, separated by month, trawling method and period (VRZ: before (NO) and after (YES) the implementation of the VRZs). Source: ARK database.

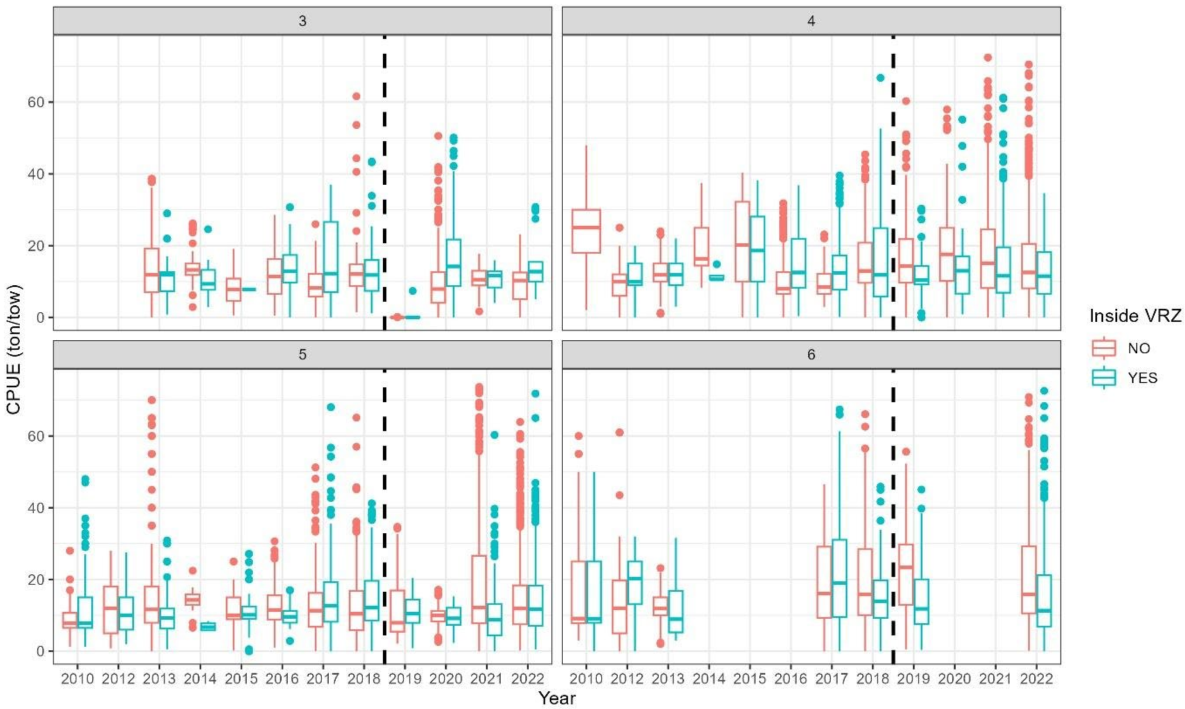

Figure 4. CPUE1 (ton per tow) estimate for the 5 days before (red) and after (cyan) entering a VRZ.

Operational costs

The total trigger level for Subarea 48.1 has been caught each fishing season from 2012/13 onwards (Fig. 2), suggesting that, at the fleet level, the VRZ has not affected overall catch levels.

However, it is likely that any effect would be felt at the *vessel* level, for which we conducted an analysis of fishing performance on vessels active before and after the introduction of the VRZs, which included five vessels. On a tow-by-tow basis, *vessel* explained most of the deviance in fishing performance, with the best model *log*(CPUE1 +1) ~*Vessel + Month + Year + VRZ_in* explaining 27.5% of the total deviance. Nonetheless, the best model did not include the introduction of VRZs ("VZ_period", Table 4). By contrast, the best model on CPUE2, *log*(CPUE2 + 1) ~ *Vessel + Month + VRZ_in + VRZ_period + No. ships*, explaining 27.8% of the total deviance, included the introduction of VRZs (Table 5; Fig. 5). The introduction of VRZs had a negative influence on the CPUE2 (VRZ_periodYES: coeff = -0.263, SE = 0.038, $p < 0.000$). Finally, the best mean daily catch per month model, explaining 47.9% of total deviance, included *Vessel + VRZ_in + Month* (Table 6).

Total fishing effort, measured as the number of fishing days per season, declined during the study period (Fig. 6; Season: coeff = -3.282, SE = 1.056, $p = 0.003$). Similarly, total catch per vessel decreased since the introduction of VRZs (VRZ_periodYES: coeff = -0.2779, SE = 0.1011, $p = 0.009$), after adjusting by *vessel* differences (Table 7). Finally, total distance traveled between hauls was best explained by fishing method (Table 7), with traditional trawlers moving more distance overall (Fig. 6).

Table 4. Analysis of VRZ effect on catches and CPUE1 (ton/tow).

A. CPUE 1, catch per tow: log(Ton/tow +1) ~

Mod #	Predictors	Deviance explained	Chi.sq	DF	*p*Chi.sq	AIC value	BIC value
1	Vessel	19.3%	4145.197	4	<0.000	91649.02	91702.36
2	Vessel + Mo	24.9%	5352.844	11	<0.000	87799.65	87915.2
3	Vessel + Mo + Years	27.4%	5895.238	20	<0.000	85987.46	86183.01
4	Vessel + Mo + Years + VRZ_in	27.5%	5911.915	21	<0.000	85932.19	86136.62
5	Vessel + Mo + Years + VRZ_in+ VRZ_period	27.5%	5911.915	21	<0.000	85932.19	86136.62
6	Vessel + Mo + Years + VRZ_in + VRZ_period+ No.Ships	27.5%	5911.915	21	<0.000	85932.19	86136.62
7	Vessel + Mo + Years + VRZ_in + VRZ_period + Fish_method+ No.Ships	27.5%	5911.915	21	<0.000	85932.19	86136.62

Vessel : character, vessel code
Mo : character, month names
Years : character, years
VRZ_in : YES = inside a VRZ, NO = outside a VRZ
VRZ_period : YES = during ARK Commitment (2019-2022), NO = before ARK Commitment (2010-2018)
No.Ships : numeric, no. ships fishing that season

B. Model comparison using rcompanion::compareGLM

Mod #	Formula: log(Krill_catch + 1) ~	Rank	AICc value	BIC value
1	Vessel	5	91650	91700
2	Vessel + Mo	12	87800	87920
3	Vessel + Mo + Years	21	85990	86180
4	Vessel + Mo + Years + VRZ_in	22	85930	86140
5	Vessel + Mo + Years + VRZ_in + VRZ_period	22	85930	86150
6	Vessel + Mo + Years + VRZ_in + No.Ships	22	85930	86150
7	Vessel + Mo + Years + VRZ_in + Fish_method	22	85930	86150
8	Vessel + Mo + Years + VRZ_period + No.Ships	21	85990	86200
9	Vessel + Mo + Years + VRZ_period + Fish_method	21	85990	86200
10	Vessel + Mo + Years + VRZ_in + VRZ_period + Fish_method + No.Ships	22	85940	86170

Table 5. Analysis of VRZ effect on catches and CPUE2 (ton/day).

A. CPUE 2, Daily catch: log(Ton/day + 1) ~

Mod #	Predictors	Deviance explained	Chi.sq	DF	*p*Chi.sq	AIC value	BIC value
1	Vessel	0.22	1159.288	4	<0.000	11198.0	11235.5
2	Vessel + Mo	0.257	1351.992	11	<0.000	11026.5	11107.9
3	Vessel + Mo + VRZ_in	0.269	1414.273	12	<0.000	10966.6	11054.2
4	Vessel + Mo + VRZ_in + VRZ_period	0.275	1447.33	13	<0.000	10935.4	11029.2
5	Vessel + Mo + VRZ_in + VRZ_period + No_ships	0.278	1463.504	14	<0.000	10921.0	11021.1
6	Vessel + Mo + VRZ_in + VRZ_period + No_ships + Fish_method	0.278	1463.504	14	<0.000	10921.0	11021.1
7	Vessel + Mo + VRZ_in + VRZ_period + No_ships + Fish_method + Season	0.278	1465.844	15	<0.000	10920.6	11027.0

Vessel : character, vessel code
Mo : character, month names
Season : number, years
VRZ_in : YES = inside a VRZ, NO = outside a VRZ
VRZ_period : YES = during ARK Commitment (2019-2022), NO = before ARK Commitment (2010-2018)
No_Ships : numeric, no. ships fishing that season
Fish_method : 'continuos pump' or 'traditional'

B. Model comparison using rcompanion::compareGLM

Mod #	Formula: log(Ton/day + 1) ~	Rank	AICc value	AIC weight	BIC value
1	Vessel	5	11200	0.00000	11240
2	Vessel + Mo	12	11030	0.00000	11110
3	Vessel + Mo + VRZ_in	13	10970	0.00000	11050
4	Vessel + Mo + VRZ_in + VRZ_period	14	10940	0.00002	11030
5	Vessel + Mo + VRZ_in + VRZ_period + No_ships	15	10920	0.33333	11020
6	Vessel + Mo + VRZ_in + VRZ_period + No_ships + Fish_method	15	10920	0.33333	11030
7	Vessel + Mo + VRZ_in + VRZ_period + No_ships + Fish_method + Season	16	10920	0.33333	11040
8	Fish_method + Mo + VRZ_in + VRZ_period + No_ships	12	11120	0.00000	11200

Summary, Model 6:

```
glm(formula = log(Catch_day + 1) ~ Vessel + Mo + VRZ_in + VRZ_period +
    No_ships + Fish_method, family = gaussian, data = data.day)

Coefficients: (1 not defined because of singularities)
                       Estimate Std. Error t value Pr(>|t|)
(Intercept)             5.45847    0.13331  40.946  < 2e-16 ***
Vessel-2                   -1.71110    0.05330 -32.104  < 2e-16 ***
Vessel-3            -1.26129    0.05212 -24.197  < 2e-16 ***
Vessel-4                   -0.47443    0.04908  -9.666  < 2e-16 ***
Vessel-5            -1.17733    0.04920 -23.930  < 2e-16 ***
```

```
MoDecember              -1.08694    0.09866 -11.017  < 2e-16 ***
MoFebruary              -0.42770    0.08526  -5.017 5.50e-07 ***
MoJanuary               -0.71198    0.09846  -7.231 5.75e-13 ***
MoJuly                   0.45453    0.11385   3.993 6.66e-05 ***
MoJune                   0.17219    0.05515   3.122  0.00181 **
MoMarch                 -0.16885    0.05161  -3.272  0.00108 **
MoMay                    0.01993    0.04183   0.477  0.63374
VRZ_inYES               -0.26706    0.03570  -7.481 9.07e-14 ***
VRZ_periodYES           -0.26285    0.03809  -6.901 6.03e-12 ***
No_ships                 0.05110    0.01264   4.043 5.37e-05 ***
Fish_methodtraditional        NA         NA      NA       NA
---
Null deviance: 5264.2  on 3856  degrees of freedom
Residual deviance: 3800.7  on 3842  degrees of freedom
AIC: 10921
Number of Fisher Scoring iterations: 2
```

Table 6. Analysis of VRZ effect on CPUE3, monthly daily catches (ton/day).

A. CPUE 3, Monthly average of daily catches, log(mean catch per day +1) ~

Mod #	Predictors	Deviance explained	Chi.sq	DF	*p*Chi.sq	AIC value	BIC value
1	Vessel	0.368	116.581	4	<0.000	749.0	771.4
2	Vessel + VRZ_in	0.402	127.268	5	<0.000	734.3	760.4
3	Vessel + VRZ_in + Mo	0.479	151.803	12	<0.000	706.0	758.1
4	Vessel + VRZ_in + Mo + Fish_method	0.479	151.803	12	<0.000	706.0	758.1
5	Vessel + VRZ_in + Mo + Fish_method + VRZ_period	0.483	152.960	13	<0.000	705.9	761.7
6	Vessel + VRZ_in + Mo + Fish_method + VRZ_period + No.Ship	0.486	154.066	14	<0.000	705.8	765.3

Vessel : character, vessel code
Mo : character, month names
VRZ_in : YES = inside a VRZ, NO = outside a VRZ
VRZ_period : YES = during ARK Commitment (2019-2022), NO = before ARK Commitment (2010-2018)
No_Ships : numeric, no. ships fishing that season
Fish_method : 'continuos pump' or 'traditional'

B. Model comparison using rcompanion::compareGLM

Mod #	Formula: log(Mean.catch.day + 1) ~	Rank	AICc value	AIC weight	BIC value
1	Vessel	5	749.3	0.00000	771.4
2	Vessel + VRZ_in	6	734.7	0.00000	760.4
3	Vessel + VRZ_in + Mo	13	707.5	0.25828	758.1
4	Vessel + VRZ_in + Mo + Fish_method	13	709.7	0.08597	763.8
5	Vessel + VRZ_in + Mo + Fish_method + VRZ_period	14	709.7	0.08597	767.4
6	Vessel + VRZ_in + Mo + Fish_method + VRZ_period + No.Ship	15	709.9	0.07779	771.0
7	Vessel + VRZ_in + Mo + VRZ_period	14	707.5	0.25828	761.7
8	Vessel + VRZ_in + Mo + VRZ_period + No.Ship	15	707.7	0.23370	765.3

Table 7. Changes in overall fishing effort (no. fishing days; distance traveled) and catches per vessel and season.

No. of fishing days per season:

A. Fishing effort, No.Days ~

Mod #	Predictors	Deviance explained	Chi.sq	DF	*p*Chi.sq	AIC value	BIC value
1	Season	0.18	3910.59	1	0	410.66	416.15
2	Season + VRZ_period	0.156	3385.37	1	0	412.00	417.48
3	Season + VRZ_period + Fish_method	0.038	821.16	1	0	418.02	423.50

B. Model comparison using rcompanion::compareGLM

Mod #	Formula: No.Days ~	Rank	AICc value	AIC weight	BIC value
1	Season	2	411.2	0.3093	416.1
2	Season + VRZ_period	3	413.4	0.1030	419.7
3	Season + VRZ_period + Fish_method	4	413.7	0.0886	421.3
4	Season + VRZ_period + No.Ships	4	414.8	0.0511	422.4
5	Season + VRZ_period + Vessel	7	412.9	0.1322	423.7
6	VRZ_period + Fish_method	3	412.7	0.1461	419.1
7	Season + No.Ships	3	412.4	0.1697	418.7

Summary, Model 1:

```
Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 6695.951   2130.311   3.143  0.00299 **
Season        -3.282      1.056  -3.108  0.00330 **
---
Null deviance: 21725  on 45  degrees of freedom
Residual deviance: 17814  on 44  degrees of freedom
AIC: 410.66
```

Total distance traveled (nm) per season:

A. Log(Dist.nm) ~

Mod #	Predictors	Deviance explained	Chi.sq	DF	*p*Chi.sq	AIC value	BIC value
1	Fish_method	0.128	0.781	1	0.306	37.46	42.94
2	Fish_method + Vessel	0.283	1.731	4	0.182	34.43	45.41
3	Fish_method + Vessel + Season	0.034	0.205	1	0.795	42.17	47.65

B. Model comparison using rcompanion::compareGLM

Mod #	Formula: log(Dist.nm) ~	Rank	AICc value	AIC weight	BIC value
1	Fish_method	2	38.03	0.3462	42.94
2	Fish_method + Vessel	5	39.38	0.1763	49.23
3	Fish_method + Vessel + Season	6	39.76	0.1458	50.5
4	Fish_method + Vessel + No.Ships	6	42.19	0.0433	52.93
5	Fish_method + No.Ships	3	40.38	0.1069	46.72
6	Fish_method + VRZ_period	3	39.89	0.1366	46.23
7	Fish_method + VRZ_period + No.Ships	4	42.11	0.0450	49.75

<u>Total catch (ton) per season</u>:

A. log(Catch.tot) ~

Mod #	Predictors	Deviance explained	Chi.sq	DF	*p*Chi.sq	AIC value	BIC value
1	Vessel	0.793	20.745	4	0	44.074	55.046
2	Vessel + Fish_method	0.665	17.405	1	0	60.199	65.685
3	Vessel + Fish_method + Season	0.025	0.646	1	0.359	109.419	114.905

B. Model comparison using rcompanion::compareGLM

Mod #	Formula: log(Catch.tot) ~	Rank	AICc value	AIC weight	BIC value
1	Vessel	5	46.23	0.0410	55.05
2	Vessel + Fish_method	5	49.02	0.0102	58.87
3	Vessel + Fish_method + Season	6	43.81	0.1375	54.55
4	Vessel + Fish_method + VRZ_period	6	44.01	0.1244	54.75
5	Vessel + No.Ships	6	47.66	0.0201	57.51
6	Vessel + VRZ_period	6	41.07	0.5412	50.92
7	Vessel + VRZ_period + No.Ships	7	43.99	0.1257	54.73

Summary, Model 6:

```
               Estimate Std. Error t value Pr(>|t|)
(Intercept)     10.6394     0.1211  87.874  < 2e-16 ***
Vessel-2           -1.8754     0.1640 -11.433 3.54e-14 ***
Vessel-3     -1.5919     0.1550 -10.268 8.95e-13 ***
Vessel-4           -0.5363     0.1550  -3.459  0.00130 **
Vessel-5     -1.1701     0.1590  -7.360 5.95e-09 ***
VRZ_periodYES      -0.2779     0.1011  -2.748  0.00895 **
---
Null deviance: 26.1543  on 45  degrees of freedom
Residual deviance:  4.5499  on 40  degrees of freedom
AIC: 38.12
```

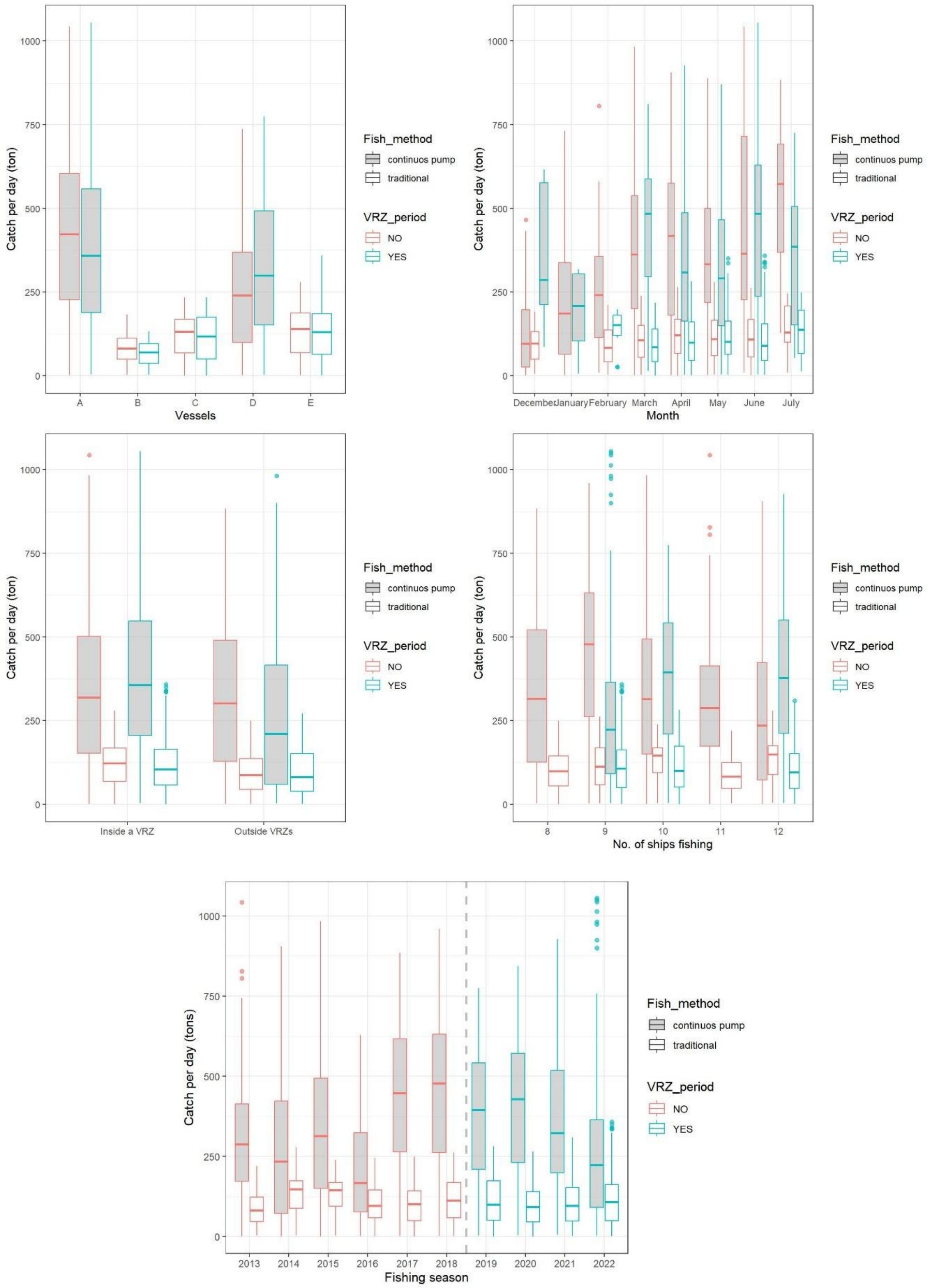

Figure 5. Main variables used for CPUE2: daily catches (ton/day).

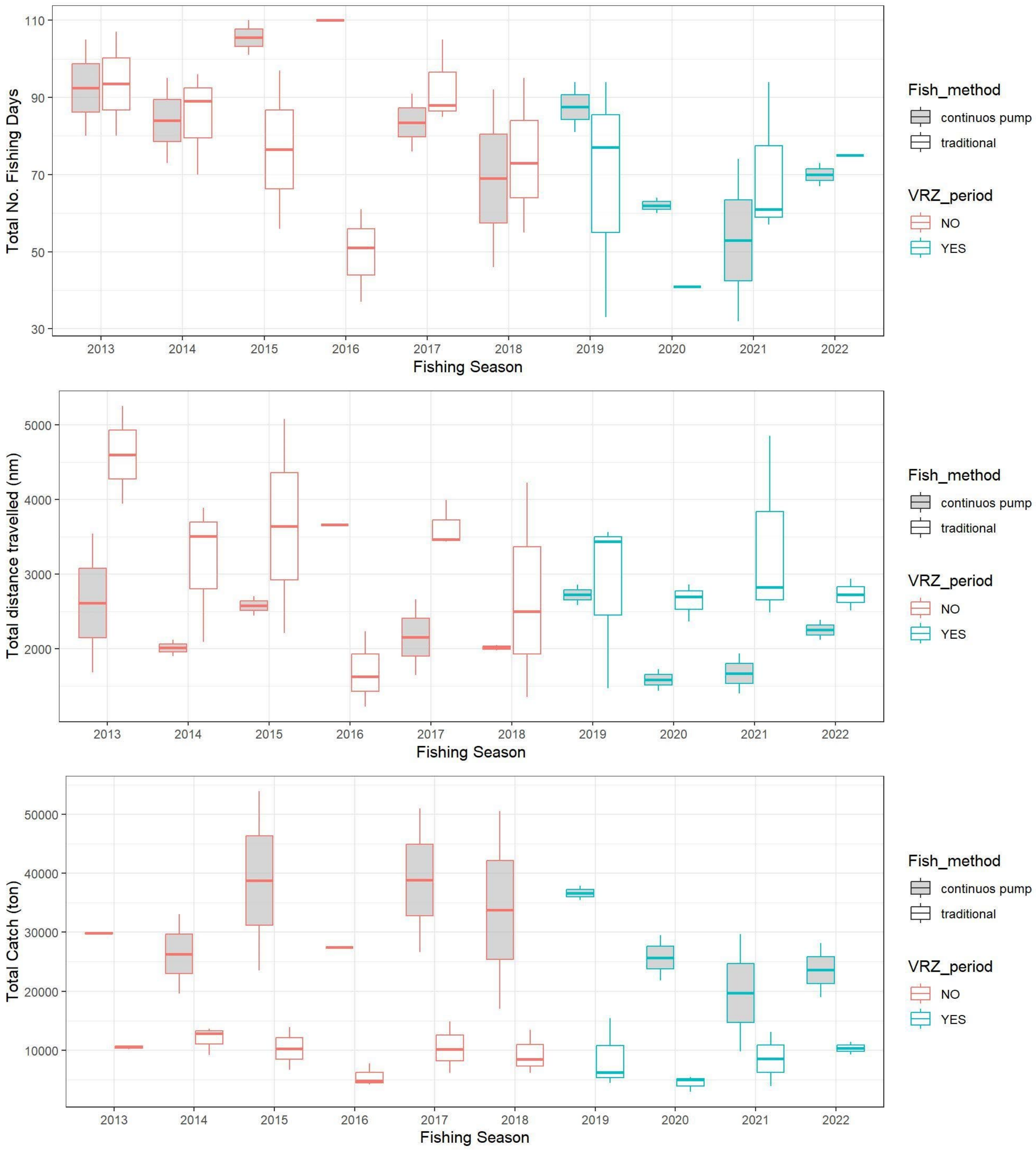

Figure 6. Total number of fishing days, distance travel between hauls, and catch per season.

Discussion

Best Commercial Effort

The BCE analyses suggest that the introduction of VRZs in the 2019 fishing season contributed to reducing catches inside the VRZs even after the lifting of the seasonal protection period. The main variables explaining changes in the proportion of catches inside/outside VRZs from March to July, after the lifting of the seasonal closure, were Month and the interaction between Month and VRZ (Table 1c). A review of the spatial distribution of catches before the establishment of the VRZs suggests that during summer (particularly December-January) and winter (July-October) months, catches used to be inside the VRZs areas, and this pattern changed once the VRZs were implemented (Fig. 3). This pattern was exacerbated since 2019, particularly during April and May, when the fleet fished mainly outside the VRZs.

The BCE principles indicate that fishing inside VRZ should be conducted after testing the area outside and finding low fishing performance. We tested this principle by comparing fishing effort and CPUE on the 5 days before and after entering a VRZ. Our results suggest that catches and effort before entering the VRZ were in general higher, thus, there was no improvement by entering the VRZ (Table 2). Likewise, the CPUE inside the VRZ was lower than the monthly CPUE, suggesting no benefits from entering the VRZ; the CPUE before entering the VRZ was similar to the monthly average (Table 2). Interestingly, the fishing effort after entering a VRZ was significantly lower than the 5 previous days, indicating that entering a VRZ does not typically improve vessel performance. These results also suggest that incursions into VRZs were short-lived, which would explain the overall reduction in catches inside the VRZs. A further spatial analysis to test this hypothesis is recommended.

We also tested for a decrease in fishing performance as a signal for seeking new fishing grounds and entering a VRZ. The mean slope in CPUE was not different from zero during the whole study period, suggesting this was not the main cause for entering a VRZ.

Fishing cost

The establishment of the VRZs had not affected the capacity of the fleet from capturing the entire trigger level for Subarea 48.1 from 2012/13 onwards. However, any potential effect may be better reflected at the vessel level, as the fleet has changed in composition and size over the years. We compared same vessel performance before and after the introduction of the VRZs.

The importance of the introduction of VRZs depended on the measure of fishing performance used. VRZs had no effect on CPUE1 (ton per tow; Table 4). By contrast, VRZs were significant in explaining changes in CPUE2 (ton per day). CPUE2 was best explained by differences in vessel, month, catches inside VRZ, VRZ period and No. of fishing ships (Fig. 5). Daily catches are higher in continuous trawlers, lower during the early season (December-February), higher inside VRZs and overall, lower since the introduction of the VRZs (coeff = -0.263 $p < 0.000$; table 5).

Accordingly, the average catch per vessel per season decreased since the introduction of the VRZs. Likewise, there was a decrease in the average number of fishing days during the study period (Fig. 6; Table 7). It is not clear why fishing effort, and catches, decreased in recent years. Potential causes include changes in the composition and experience of the fishing fleet.

3. Current status on predators (science, data and analysis)

Penguin Population Trends

Summary

The ongoing population declines in two of the three pygoselid penguin species in Subarea 48.1 is likely to maintain public interest in conservation efforts to protect these species. While there is some evidence that these populations may be sensitive to the effects of krill fishing, there is no evidence that krill fishing is the sole driver of these declines. It is possible to conceive of the VRZs as part of an experiment to determine whether temporal closure during the breeding season would such measures can help to reverse, halt or slow such declines. However, this would require a level of data collection and analysis that is currently unavailable. The collection of data on penguin populations was severely affected by the covid pandemic which began in the second fishing season after the VRZs were established, thus few data exist to make comparisons during the treatment period. Given the limited data and scientific resources available, as well as a coherent control/treatment design, it is unrealistic to expect a demonstrable positive/negative/neutral impact of the VRZs in the short term.

Assessment of Penguin population changes since inception of the VRZs

There have been several publications in recent years indicating the continued decline in Chinstrap and Adélie penguin populations, particularly in the Western Antarctic Peninsula (WAP–generally Subarea 48.1) (Casanovas et al. 2015 and references cited therein; Stryker et al. 2020 and references cited therein; Kruger et al. 2023). However, there are simply too few data to draw any inference on the effectiveness, impact or consequence to penguin populations from the VRZs based on this 5-year review. In part this is due to attenuated data collection as result of the pandemic during the analysis period, but also reflects the nature and scale of the issues under examination:

1) the time frame required for detecting changes at the breeding population level for penguins is >4-5 years (e.g., Gao et al. 2023);
2) accounting for environmental variability in the drivers of penguin population change requires a more robust and extensive sampling regime (e.g., Salmeron et al. 2023);
3) lack of correlates to compare fished versus unfished areas for response;
4) the need for a finer scale management zones to assess impact (e.g., Kruger et al 2023); and
5) lack of resources needed to focus data collection and analysis specific to this question.

The three predominant penguin species within Subarea 48.1 are the Pygoscelids. While somewhat similar in life history, both Adélie penguins and Gentoo penguins have attributes that make them less useful as indicator species relative to Chinstrap penguins. Gentoo penguins are far more plastic in diet, making them less dependent on krill (thus less responsive to changes in krill abundance); they are much more plastic in site fidelity, meaning they will relocate under unfavorable conditions more readily than the other two Pygoscelids; and they are generally increasing in numbers throughout Subarea 48.1, which complicates any impact analysis. Adélie penguins, while are more obligate krill predators, are generally believed to associate strongly with sea ice, which due to its increasingly variable occurrence, would require a greater understanding of sea ice dynamics in addition to prey abundance and occurrence in order to detect impacts from fishing. Adélie penguin populations are believed to be stable in the eastern (Weddell Sea) portion of Subarea 48.1, and in the southernmost portions of the Western Antarctic Peninsula, which also have limited fishing.

The reasons outlined above suggest that Chinstrap penguins would be the most sensitive to krill abundance fluctuations among the Pygoscelids occurring in Subarea 48.1, and therefore the preferred species to assess as response indicators to fishing pressure. From 2018-2023, only 133 census points were collected on Chinstrap penguins in Subarea 48.1 (MAPPPD [Humphries et al. 2017] accessed 5/30/2023 and Oceanites, Inc. unpublished data 2022-2023), which comprised 97 unique sites with a prior census history. Of these, only eight (South Shetlands: Half Moon, Ardley Islands, Barton Peninsula; Gerlache Strait: Georges Point, Selvick Cove, Tetrad Island and Skottsberg Pt; Elephant Island: Stinker Point) contained more than one data point through the analysis period, the majority for only two years out of five.

Of this dataset of eight sites, each of which contained two or more census points during the analysis period 2018-2023, 5 declined, 2 increased, and one remained unchanged (Fig. 7). Of the 97 Chinstrap sites censused with at least one count in the period 2018-2023 within Subarea 48.1, which also had previous census history, 75 recorded census populations lower than the previous period or most recent census record (declined-77%), 14 recorded census populations higher than the previous period (increased-14%), and 8 were essentially unchanged (stable-8%).

No attempt to make any characterization from these observations (e.g., BACI: before/after/ control/impact) with respect to the VRZs and their relative effectiveness has been made for the reasons cited above. The data is provided to give some sense of the scope of effort required to show with some certainty that the VRZs alone could have an effect on breeding population trends or mitigating negative population trends. As we have also previously suggested, reduction in competition for krill during the penguin breeding period is inherently beneficial to penguins rearing chicks (see e.g., Kruger et al. 2023) but it does not necessarily mitigate competition outside of the breeding season that could impact population dynamics over the course of the penguin's life history. If the Review Panel deems that it is critical to obtain a more quantifiable measure of how effective the VRZs are for penguins, then the deficiencies cited above will need to be addressed going forward.

Relevant new science regarding penguins

Kruger (2023) commented on the vulnerability of chinstrap penguin populations in the Western Antarctic Peninsula and Scotia Sea (Subareas 48.1 and 48.2) generally, noting that 60% of the global population resides there and that most recent evidence points to a 30% reduction in population over the last several decades, along with increasing environmental variability, warranting heightened conservation concern (but see response from Oosterhuizen et al. 2023, described below, for response and critique). The results are also in line with the end of the krill surplus hypothesis (Trivelpiece et al. 2011, Pallin et al. 2023) suggesting that penguins would be decreasing since the late 1970s due to the recovery of whaling and climate change.

Oosthuizen et al. (2023) presented a critique of the methodology applied by Kruger (2023), indicating both problems with the existing historical dataset for making accurate predictions of future trends, and that Kruger may have overstated the magnitude of declines predicted as well as observed declines given the reliability of some historical and current estimates. Problems with variability of small numbers of nesting penguins at small colonies is also noted as affecting the robustness of analyses. Regardless, CCAMLR "…noted that the decline of chinstrap penguins is of concern and that while analytical approaches differed between the two papers, both WG-EMM-2023/P06 and WG-EMM-2023/41 supported the finding of decreasing population trends."

Kruger et al. (2023-non peer-reviewed preprint) provided an historical (1995-2018) analysis of krill fishing and impacts to penguins during the breeding season. Kruger et al. binned the reproductive success (measured as number of nearly-fledged chicks) into three categories, and assessed krill harvest rates in two zones (around the South Shetland Islands) by year with concurrent estimates from krill acoustic biomass data to obtain estimates of total catch as a percentage of krill availability. "The median number of chicks raised per nest in the colonies within the fishing strata was lower than 1.00 in years when harvest rate was above 5% and krill biomass was below the median. In contrast, the number of chicks raised per nest ranged between 0.9 and 1.25 when catch was <5% and krill biomass was below median, and between 1.10 and 1.30 with krill biomass above median." The authors concluded that, "Our analysis indicates that krill removals have had detectable impact over breeding success of Pygoscelis penguins in the West and Bransfield strata. In periods of low krill biomass, the catch limit can represent a substantial amount of the local krill biomass, likely resulting in interference competition. Our results identified localized effects of the krill fishery in the WAP, reinforcing the need to allocate catch limits over smaller spatial scales, to ensure the application of CCAMLR's precautionary management approach."

The data used in this analysis predates the VRZs established in 2018. However, the study indirectly supports the VRZ concept, in that the authors note that in some instances, reproductive success was very low when fishing was occurring inshore during the breeding season. In terms of removal of krill biomass, the fishing described occurred between December and March, so it remains a question whether removal of biomass post penguin fledging, or removing biomass regionally (outside the VRZs) would have a similar effect. The opportunity provided by this analysis to compare with a post-treatment VRZ model should be considered (but see WG-EMM-2023? for possible robustness of conclusions and model improvements).

Salmerón et al. (2023) used radio telemetry and acoustic krill surveys to evaluate penguin response to different levels of krill availability off Nelson Island (South Shetland Islands). "Our results showed that chinstrap penguins adjusted their foraging behavior to low krill availability conditions by performing longer trips with deeper and more frequent dives, with likely consequences on breeding success. Increased foraging effort is a common response of central place foragers to decreased food availability." Breeding success, as measured in terms of chicks reared/nest, declined in the year of low food availability, from above 0.8 chicks/nest to below 0.5 chicks/nest. The authors did not measure the effects of fishery, but hypothesized that, "in a season when environmental conditions are not favourable, such as 2021/22, high levels of fishing could affect the krill population itself and, therefore, lead to punctual effects over penguin populations." As above, this study indirectly supports the VRZ concept.

Riaz et al. 2023 assessed how penguin foraging effort in East Antarctica changed in relation to krill swarm abundance and distribution by spatially integrating two years of krill acoustic data with contemporaneous penguin movement data. "Our findings show that penguin diving effort was focused in areas with a high number of krill swarms, yet they did not focus their effort in areas with high krill biomass". This highlights the importance of encounter frequency with smaller patches, rather than total biomass, unlike foraging strategies for whales, which require large aggregations of krill. The authors speculate that, "[it] is also plausible the foraging effort of whales disperses large biomass krill swarms, creating a krill prey-field more favorable to penguins." If true, this not only suggests further refinement in terms of assessment of local krill stocks but could also suggest intriguing modifications to harvest methods that allow krill escapement to mimic foraging patterns of whales to benefit penguins.

Gao et al. (2023), in modelling sea ice retreat and subsequent krill recruitment losses, identified a 4-year lag between reduced krill recruitment and negative population responses in penguin populations. While this paper dealt with recruitment and not harvest of adult krill, the principles are likely the same, in that most recruitment of breeding penguins does not occur until age three, so failures in breeding success would be lagged accordingly.

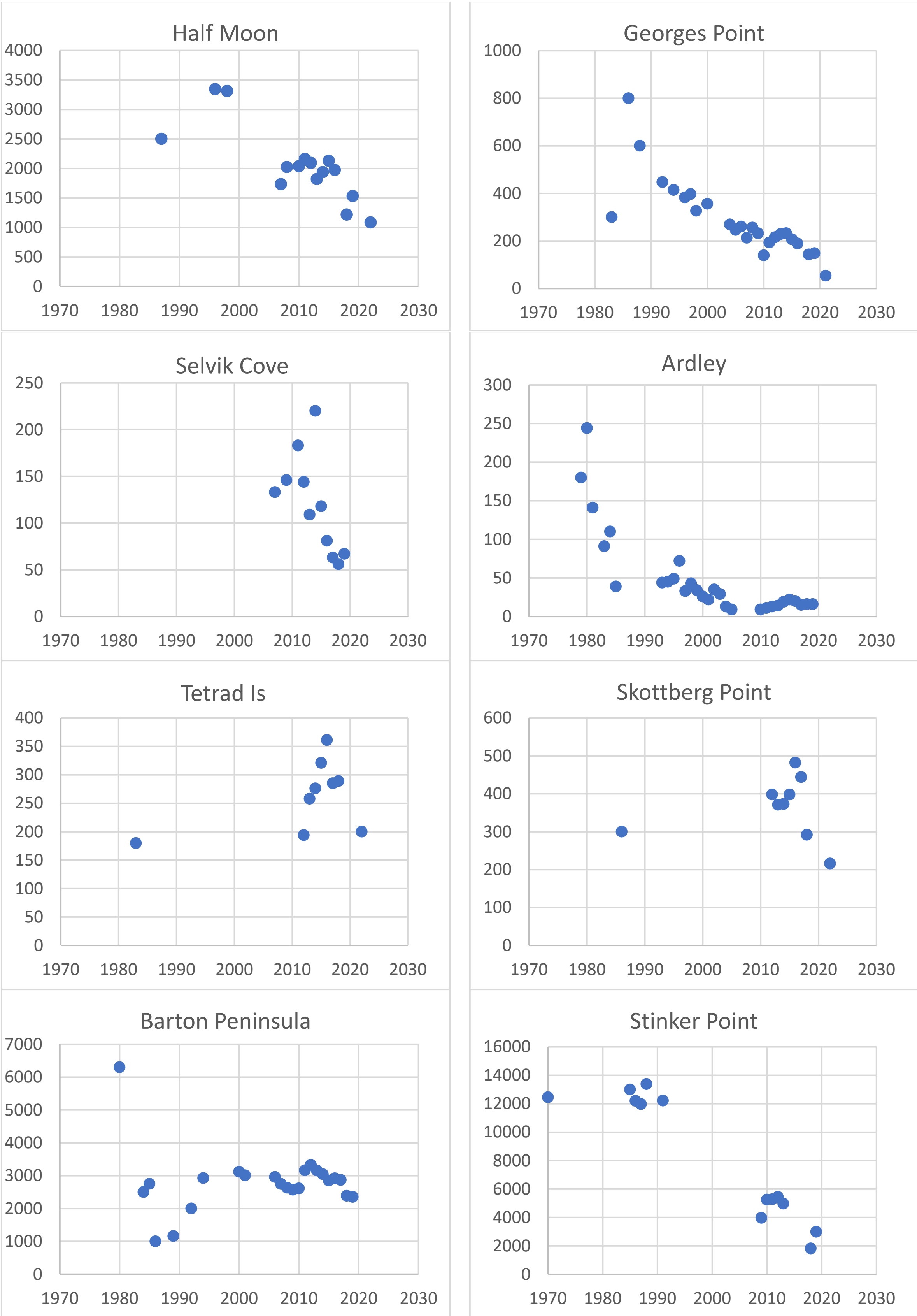

Figure 7. Census history for eight chinstrap penguin sites where at least two data points were obtained during the period 2018-2023 (8 charts).

Population status of baleen whales along the Western Antarctic Peninsula

Context

During the 20th century, more than 2 million whales were caught in the Southern Hemisphere (Rocha Jr. et al. 2015), bringing some species, like Antarctic blue whales (Balaenoptera musculus intermedia), to near extinction (Branch et al. 2007). This massive removal of consumers from Southern Ocean ecosystems led to the hypotheses that there should be a 'krill surplus' under the assumption that baleen whales exert strong top-down control on krill through consumption (Laws 1977). Pre-whaling populations of baleen whales are estimated to have consumed 430 million tonnes of Antarctic krill annually (Savoca et al. 2021). Following whaling, 379 million tonnes of Antarctic krill annually are estimated to have been left unconsumed (Savoca et al. 2021). Ecosystem modelling supports competitor release as a plausible explanation for some observed penguin and seal population increases in the 20th century, supporting the krill surplus hypothesis to an extent (Surma et al. 2014); for example, see (Hoffman et al. 2022) for a demographic reconstruction of Antarctic fur seals.

However, some penguin and seal populations have declined over the last decades of the 20th century (see sections on penguins and seals), and Antarctic krill abundance may have decreased (Atkinson et al. 2004, see discussion in Cox et al. 2018, Hill et al. 2019, Krafft et al. 2021): the 'krill paradox'. Certainly, current krill biomass is estimated to be insufficient to have supported pre-whaling Southern Ocean whales (Savoca et al. 2021).

Baleen whales play an important role in cycling of iron—a limiting micronutrient in the Southern Ocean (Nicol et al. 2010, Lavery et al. 2014, Roman et al. 2014, Ratnarajah et al. 2014). Before whaling, baleen whales are estimated to have recycled 1.2 x 10^4 tonnes of iron per year in the Southern Ocean, compared to 1.2 x 10^3 tonnes of iron per year today (Savoca et al. 2021), and reduced iron fertilization is one of the possible causes of decreased krill abundance (Smetacek 2008, Nicol et al. 2010). Even during the pre-whaling era, however, Maldonado et al. (2016) have estimated that the contribution of baleen whales to iron recycling in the Southern Ocean is negligible compared to that of planktonic consumers (mainly microzooplankton, krill and salps).

Population status

Six species are considered Antarctic baleen whales: humpback (*Megaptera novaeangliae*), blue (*Balaenoptera musculus intermedia*), Antarctic minke (*Balaenoptera bonaerensis*), fin (*Balaenoptera physalus*), sei (*Balaenoptera borealis*) and southern right (*Eubalaena australis*) whales (Leaper & Miller 2011). Generally, there is insufficient information on the abundance and population trends of baleen whales, and this is true for populations using the Western Antarctic Peninsula region. Globally, humpback whales are listed as Least Concern with an increasing trend on the IUCN Red List (Cooke 2018d), Antarctic blue whales are considered Critically Endangered with an increasing trend (Cooke 2018b), fin whales are considered Vulnerable with an increasing trend (Cooke 2018c), Antarctic minke whales are considered Near Threatened with an unknown trend (Cooke et al. 2018), sei whales are considered Endangered with an increasing trend (Cooke 2018a) and southern right whales are considered Least Concern with an unknown trend (Cooke & Zerbini 2018). The most relevant species in terms of the krill fishery along the Western Antarctic Peninsula currently are humpback, minke and fin whales.

Humpback whales
Of these six species, humpback whales are arguably the best-known along the Western Antarctic Peninsula, corresponding to Subarea 48.1. An abundance of up to 19,107 humpback whales was estimated for the Bransfield and Gerlache Strait, based on data collected from platforms of opportunity in the austral summer of 2019/2020, a significant increase from the 7,000 individuals estimated in 2000 (Johannessen et al. 2022). From 2010-2016, 63.5% of females sampled in the Western Antarctic Peninsula were pregnant with great interannual variation (Pallin et al. 2018). The high overall pregnancy rate is consistent with a recovering population, supported by increasing abundance estimates for southeast Pacific humpback whales (e.g., Johnston et al. 2011, Jackson et al. 2015). The Western Antarctic Peninsula is traditionally recognized as the feeding grounds of southeast Pacific humpback whales (Breeding Stock G). However, evidence of summer co-occurrence of the Breeding stock A and Breeding Stock G at the Western Antarctic Peninsula pointed to a need to revise perceptions of boundaries between stocks and ocean basins (Marcondes et al. 2021). Pallin et al. (2023) showed that pregnancy rates for humpback whales along the Western Antarctic Peninsula increased with increasing krill abundance in the previous year, and with later start of sea ice edge retreat (i.e., a longer sea ice season) one and two years before. The study demonstrates a clear link between potential reproductive output and krill abundance and sea ice conditions. Three humpback whale incidental mortalities were recorded by the krill fisheries in 2021, the first for this species, (CCAMLR Secretariat 2021) and one incidental mortality was recorded in 2022 (CCAMLR Secretariat 2022). Models using humpback whale tracking data indicated that potential interactions between fisheries and humpback whales in Subarea 48.1 are greatest in May-June, in the Bransfield Strait east and west Small Scale Management Units (Reisinger et al. 2022).

Fin whales
Fin whales were heavily hunted at the northern tip of the Antarctic Peninsula (Kemp & Bennett 1932) and very few fin whales were observed in that region from 1978-1998 (Branch & Butterworth 2001). Recent observations of large foraging aggregations up to 150 animals off Elephant Island suggest that fin whales may be returning to these historical whaling grounds (Herr et al. 2022b). In part of Subarea 48.1, comprising the waters around Elephant Island and the South Shetland Islands, abundance of fin whales was estimated at 7,909 individuals (95% confidence interval: 1047–15,743) in the austral summer feeding season of 2018, up from 4672 (CV = 42.37) in 2000 (Herr et al. 2022b). The highest densities were estimated around Elephant Island, and along the shelf edge west of the South Shetland Islands, with comparatively low densities in the Bransfield Strait (Herr et al. 2022b). Previously, in summer 2016, a lower density had been estimated around Elephant Island (Viquerat & Herr 2017). Four fin whales were satellite tagged near Elephant Island in late March and early April 2021 (Herr et al. 2022a). Two tags failed while the animals were still foraging near the island, 29 and 13 days after deployment, but the remaining two whales departed from the island on 15 April, traveling north-west into the South Pacific (Herr et al. 2022a).

Antarctic blue whales
Antarctic blue whale sightings are rare: 0.17-0.52 individuals per 1000 survey km (Branch et al. 2007). The global Antarctic blue whale population was estimated at 1700 individuals in 1996, less than 1% of pre-whaling population size, but increasing at 7.3% per year (Branch et al. 2004). Like fin whales, blue whales were intensively hunted in the Antarctic Peninsula region (Kemp & Bennett 1932).

Antarctic minke whales
Antarctic minke whales have a circumpolar distribution south of 60°S (Risch et al. 2019), but are more ice-associated than other Antarctic baleen whales (Herr et al. 2019, Friedlaender et al. 2021).

Along the Western Antarctic Peninsula, tracking data show that minke whales are more restricted to sheltered bays and areas where sea ice is present (Friedlaender et al. 2021). This affinity for sea ice also presents a challenge for estimating Antarctic minke whale abundance (Williams et al. 2014, Herr et al. 2019). Circumpolar abundance south of 60°S has most recently been estimated at 515,000 individuals (95% confidence interval: 361,000-733,000) based on surveys 1992/1993-2003/2004 (IWC 2013a). This is an approximately 30% decline from the previous estimate for the period 1985/1986-1990/1991. It is statistically possible that there has been no abundance change between the two periods, but the IWC Sub-Committee on In-depth Assessments reasons that there has been a decline (IWC 2013a). Models using minke whale tracking data indicated that potential interactions between fisheries and minke whales in Subarea 48.1 are greatest in April and May, in the Bransfield Strait east and west Small Scale Management Units (Reisinger et al. 2022).

Southern sei whales
Sei whales have been caught and observed off the Western Antarctic Peninsula, but, with southern right whales, generally have a more northerly distribution than the four other baleen whale species considered here (Ropert-Coudert et al. 2014). They are rarely sighted and consequently there are no current estimates of abundance or trends in abundance for southern sei whales (*Balaenoptera borealis schlegelii*).

Southern right whales
Southern right whales have a more northerly distribution than the four other baleen whale species considered here (Ropert-Coudert et al. 2014), with primary foraging areas around 40-50°S (Derville et al. 2023). Abundance estimates are 13,611 individuals in the Southern Hemisphere in 2009 (IWC 2013b).

Projected trends

Projected recoveries of baleen whales under climate change scenarios vary among species and geographic regions (Tulloch et al. 2018). While humpback whales are projected to reach their pre-whaling abundance by 2050-2080, other species are projected to recover very slowly: for example, Antarctic blue whales are projected to reach only 32% of their pre-whaling abundance by 2100, and fin whales less than 23% (Tulloch et al. 2018).

Conclusion

Currently, there is insufficient information available to judge any effect of krill fishing or fishing area-closures, such as VRZs, on baleen whale foraging and population dynamics. Until sufficient information is available, the continued but often slow (observed and projected) recovery of whale populations, likely impacts of environmental change on krill abundance and distribution including interannual variation in baleen whale demographic parameters (Agrelo et al. 2021, Pallin et al. 2023) and potential impacts of local krill removal by fisheries, all suggest that the current absence of evidence of any fishery impact on baleen whales should not be interpreted as evidence of no impact.

Status of seals along the Western Antarctic Peninsula

Abundance, population structure

Antarctic fur seals

Antarctic fur seals (*Arctocephalus gazella*) were subjected to uncontrolled harvesting throughout their circumpolar range during the late 19th and early 20th centuries, resulting in the decimation of many breeding colonies. The subsequent post-harvest recovery has led to some populations recovering to beyond their estimated pre-harvest numbers (Boyd 1993). Indeed, one molecular study presents evidence for a two-fold larger population at South Georgia compared to its pre-harvest estimates (Hoffman et al. 2022). The authors of that study suggest that the harvesting of baleen whales over the same period released large quantities of Antarctic krill which fueled the rapid recovery of fur seals *sensu* the Krill Surplus Hypothesis. Population growth rate models and molecular data suggest that the South Georgia population of Antarctic fur seals has declined up to 24% over between 1985 and 2012 (Forcada and Hoffman 2014), yet it is worth noting that this potential decline coincides with the recovery of several baleen whale species (e.g. Herr et al. 2022b, Zerbini et al. 2019). The species is currently listed as "Least Concern" in the IUCN Redlist with a global population estimate of between 7 and 10 million mature individuals (https://www.iucnredlist.org/species/2058/66993062).

In the area of interest (Western Antarctic Peninsula), the South Shetland Islands (SSI) host the only breeding colony of Antarctic fur seals. However, telemetry studies highlight that vast numbers of male seals also perform post-breeding migrations from South Georgia into this region from late January and remain until October (Lowther et al. 2020, Drago et al. 2022). Studies detailing the genetic population structure of Antarctic fur seals indicate that the SSI population represents a distinct subgroup. Cleary et al. (2019) used high resolution Single Nucleotide Polymorphisms (SNP) to identify four population groups across the species range with South Georgia and SSI forming a single group, while Krause et al. (2021) compiled the evidence from a range of other studies (e.g., Paijmans et al. 2020) that uses coarser resolution nuclear microsatellite and mitochondrial data suggest that SSI represents a distinct breeding colony of high genetic diversity.

The SSI breeding colony has been in decline for two decades, with an 86% decline in abundance since 2007 (Krause et al. 2021). Krause et al. (2021) provide strong evidence supporting the cause of this decline being leopard seal predation on fur seal pups, with almost 70% of all pups born since 2010 being consumed, though they suggested that potentially worsening summer foraging conditions (i.e., reduced krill availability) may also be a contributing factor. Like the South Georgia population, it is worth noting that the downward trajectory of Antarctic fur seals at SSI also coincides with recovering populations of humpback and fin whales over the same period in that area.

In summary, the evidence supporting a decline of the only breeding colony of Antarctic fur seals in the Western Antarctic Peninsula is unequivocal. A clear primary cause for decline has been identified (predation of pups by leopard seals), though the drivers behind the degradation of summer foraging conditions are unclear given the lack of consideration to the influx of competing conspecifics from South Georgia and rebounding baleen whale stocks, as well as contemporary and historical krill fishing activity.

Leopard seals

Leopard seals (*Hydrurga leptonyx*) are apex predators with a circum-Antarctic distribution. Given their solitary existence, they are challenging to survey, with the most recent survey data in the region being over 24 years old (Ackley et al. 2006). Density surface models (created using Ackley et al (2006) survey data and the environmental conditions seals associated with, and then correcting estimated densities using haulout probabilities) estimated an abundance of just over 5,000 individuals in the western Antarctic Peninsula region (Forcada et al. 2012). With only a single point estimate, no trend data can be reliably estimated; the species is listed as “Least Concern” under the IUCN Redlist with a circumpolar population size of approximately 18,000 individuals and no identifiable circumpolar trend (https://www.iucnredlist.org/species/10340/45226422#population).

Leopard seals consume Antarctic krill, however recent evidence suggests that the species has a high reliance on Antarctic fur seals and Pygoscelid penguins (Krause et al. 2015, 2020) and is an acknowledged cause of decline in the former species.

Crabeater seals

Crabeater seals (*Lobodon carcinophaga*) are potentially the most numerically abundant seal in the Southern Ocean, are closely associated with pack ice, and are thought to be major consumers of Antarctic krill. Forcada et al. (2012) estimated a crabeater seal abundance throughout the Western Antarctic Peninsula of approximately 1.8 million individuals, with a potential krill removal rate of up to 20% of the standing stock in the Antarctic Peninsula area (Forcada et al. 2012). Similar to leopard seals, population trends within the Antarctic Peninsula are unknown, and the species is listed as “Least Concern” on the IUCN Redlist (https://www.iucnredlist.org/species/12246/45226918#population).

Weddell seals

Based on the same survey data collected for crabeater and leopard seals, point estimate abundances for Weddell seals (*Leptonychotes weddellii*) suggest this species is a marginal consumer of Antarctic krill, with approximately 150,000 adults inhabiting the western Antarctic peninsula (Forcada et al. 2012).

Threat protection related to the establishment of the VRZ and the fishery for Antarctic krill

To our knowledge, there have been no reports of incidental mortality of pack ice seals caused by interactions with the krill fishery; presumably due to the low densities of individuals in the northern West Antarctic Peninsula (e.g., Santora and Veit 2013). The only colonially breeding seal present in the vicinity is Antarctic fur seals on SSI, for which the available biotelemetry data indicates breeding females forage beyond the VRZ (Hinke et al. 2017) and adult males occupy a vast range (Lowther et al. 2020).

Only Antarctic fur seals have been reported as incidental mortalities from krill fishing (e.g., Arana and Rolleri 2020, CCCAMLR Secretariat Antarctic Krill fishery report 2022 https://fishdocs.ccamlr.org/FishRep_48_KRI_2022.pdf), however there is a lack of information regarding the age and sex classes of individuals taken, making it impossible to attribute the source population from which they were removed. The decline in population sizes at South Georgia and SSI and the complexity of determining the impact of fishing activity are briefly described above, and it is currently impossible to determine the efficacy of the VRZs in terms of additional protection for this species given their foraging range and interactions with other competing / predating species.

4. Progress towards adopting a D1MPA

At the time of writing this report there has not been any significant progress towards the adoption of the D1MPA proposal since the implementation of the VRZs. Below is a summary of the situation and relevant recent events.

- Two MPAs have been established in the CCAMLR Area: The South Orkney Islands Southern Shelf MPA was established in 2009 and the Ross Sea Region MPA came into force in 2017.
- Several MPA proposals are under consideration within CCAMLR, including a proposal for an MPA in CCAMLR’s planning domain 1 (D1MPA), covering Subareas 48.1 and 48.2.
- Much of the recent discussion on MPAs within CCAMLR has focused on MPA objectives and Research and Monitoring Plans (RMPs), with some members advocating that specific, measurable, achievable, relevant and timebound (SMART) objectives and RMPs should be defined before an MPA is established.
- Proponents of the current D1MPA proposal have provided several refinements to the proposal since 2018, including:
    - a simplification of the spatial structure of the proposed MPA in 2019.
    - work toward developing an RMP for the MPA.
- According to the 2022 CCAMLR Commission report “most Members supported the [D1MPA] proposal” and “considered that [priority elements of an RMP] were set out in the proposal”.
- However, Russia and China both expressed concerns about the proposal and it has not been adopted.
- Discussions within CCAMLR in 2022 also highlighted the need to consider the integration of different spatial management initiatives for the krill fishery (including the ARK VRZs, the proposed D1MPA and CCAMLR’s “new krill fisheries management approach”), in order to reduce the risk of increased aggregation of catches.
- A Special CCAMLR meeting on MPAs that took place from in June 2023 in Santiago, Chile, with the objective of agreeing a road map with milestones to move forward towards establishing three more MPAs in the Southern Ocean (including a D1MPA). No progress was achieved.

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ANNEX 1. BEST COMMERCIAL EFFORT

ARK recognizes that the implementation of the best commercial effort is a difficult issue to assess by the Expert Panel – as well as a difficult concept from an operational perspective. Nonetheless, in keeping the ARK Commitment and discussions during the Review Panel 2019, ARK will continue applying its Best Commercial Effort during the duration of the ARK Commitment.

Best Commercial Effort *(Revised 2019)*

Guidelines

- Every ARK vessel will make conscious efforts to remain outside of the VRZs year-round. Thus, fishing effort will be primarily planned and targeted to areas outside VRZs, also in periods outside of seasonal closures.

- Engagement of fishing within VRZs will proceed only after scouting of surrounding areas has been conducted, and fishing performances have proved to be insufficient.

- These guidelines apply outside of the seasonal closures of the VRZs, e.g., from 1 February to 31 October.

Operational Aspects

✓ Seasonal closures (October to end of February, depending on area) are absolute.
✓ During 1 March to 30 September, vessels affiliated to ARK will plan for and focus their commercial effort to areas outside the VRZs.
✓ Thus, fishing search efforts after March 1st should focus on areas outside the VRZs.
✓ Factors such as quality and composition of catches, wind, surf, sea-ice presence and spreading of fishery are factors that can be considered as the basis for the operational application Best Commercial Effort.
✓ All vessels should refrain from fishing in the Southern Gerlache Strait VRZ.
✓ The above will be assessed each season by comparing current fishing pattern against the distribution of the fleet for the 2009/10 – 2017/18 period.

ANNEX 2. SEASONAL COMPLIANCE WITH VRZs DURING SEASON 2022/23

Summary

- Nine krill fishing vessels operated in the 2022/23 season, seven of which are affiliated to ARK.
- Six vessels, from four of the six companies affiliated with ARK, provided haul-by-haul data.
- AIS data shows that the whole krill fishing fleet complied with the seasonal VRZ during the summer (December-February).
- By contrast, one vessel fished on 29 and 30 March 2023 inside the year-round VRZ at Hope Bay, catching 142.8 tonnes, or 0.09% of the total catch for the 2022/23 season.

Introduction

ARK Committed to several voluntary measures in 20184F[1]. One of the most well-known is the Voluntary Restricted Zones (VRZs), implemented on 1 December 2018. VRZs are seasonal protection zones to safeguard breeding penguins. Under recommendation by the Review Panel, ARK implemented on 1 December 2020 a new, year-round VRZ around Hope Bay. This report analyses the compliance of ARK's krill fishing vessels with VRZs during the 2022/23 krill fishing season.

Methods

Data Availability

Data used in this report was obtained from three different sources:

- 5-day catch reports submitted by the CCAMLR Secretary; these reports informed the total catch and number of vessels fishing on a 5-day period, and the total accumulated catch per Subarea.
- C1 data forms submitted by ARK members; these forms provide haul-by-haul information on location, effort and catch by individual vessels.
- Daily vessel distribution from the Marinetraffic.com portal; this portal provides access to the AIS position of all vessels registered.

Analyses

Haul-by-haul data from four ARK members, accounting for 6 vessels, were provided to the ARK database. Data was imported from Excel sheets and a preliminary cleaning was performed as follows: data with no catches were removed; hauls positions were filtered and corrected when obvious (i.e., -420.6 instead of -42.06), using positions for preceding/following 3 hauls; date mistakes were corrected when obvious. Clean data was processed as followed: haul distribution was estimated as the middle point between the start and end of each tow; distance between hauls was estimated and then data was filtered for speed estimates above 15 knots.

[1] https://www.ark-krill.org/ark-voluntary-measures

Data from December to February was assigned as "summer" and from March to June as "winter".

All analyses were run in R 4.2.0 (R Core Team 2022) under RStudio 2022.02.3 GNU. Packages used for analyses included the following: data manipulation: 'readr', 'openxlsx', 'dplyr', tidyverse'; spatial analysis: 'sf', 'sp', 'raster'; visualization: 'ggplot2', 'ggformula', 'tmap', 'rgeos', 'gridExtra'.

Spatial analyses were conducted using the South Pole Lambert Azimuthal Equal Area Projection, centred at longitude 50°W.

Results

Krill Catches – CCAMLR reports

A total of seven vessels affiliated with ARK participated in the fishery this season. The season commenced in Subarea 48.2 on 1 December 2022 with three vessels. Subsequently, three more vessels joined in December and one in January 2023. During the summer, one vessel made two incursions into Subarea 48.1, yielding limited catches (Table A2-1; Fig. A2-1). The fleet shifted to Subarea 48.1 between 24-29 March 2023, where it continued fishing until 13-16 June. After the closure of Subarea 48.1 on 16 June, a portion of the fleet moved to Subarea 48.3, while others returned to Subarea 48.2.

Distribution Pattern of the Fleet

The distribution of the fleet was described using (i) haul-by-haul data provided by the fishing companies and (ii) AIS positions obtained from www.MarineTraffic.com (Table A2-2).

AIS information

All vessels but one fished exclusively in Subarea 48.2 during the summer season, 1 December 2022 to 28 February 2023 (Fig. A2-2). The fleet moved into Subarea 48.1 in late March, where they remained until 13-16 June (Fig. A2-3). Between 27 March and 1 April, three vessels entered Hope Bay VRZ (see below).

Haul-by-haul data

Four companies affiliated with ARK, representing six vessels, provided haul-by-haul data (Table A2-2), which represented 100% and 80.6% of summer and winter data for Subarea 48.1, respectively (Table A2-3).

This dataset indicates a single tow of 3,56 tonnes conducted in Subarea 48.1 during summer, outside any VRZs (Fig. A2-4). During the winter period, most catches were obtained outside VRZs (Fig. A2-5, Table A2-3). However, 142.8 tonnes were caught inside Hope Bay VRZ (see below).

Compliance

All ARK affiliated vessels complied with the seasonal VRZs (December-February).

A close analysis of the AIS data revealed that between 27 March and 1 April three vessels entered Hope VRZ (Fig. A2-6). From these vessels, only FV *Saga Sea* was part of ARK at that time.

FV *Saga Sea* performed a total of 12 tows, totalizing 142.8 tonnes (0.09% of the Subarea catch limit) inside Hope Bay VRZ between 29 & 30 March 2023 (Fig. A2-6). Eight tows were recorded within 0.22 nm of the limit, and the other four tows within 1.75nm of the VRZ's limit.

Conclusions

A total of 9 vessels operated during the fishing season 2022/23, 7 of them affiliated with ARK. Only one vessel fished in Subarea 48.1 during summer, catching 3.56 tonnes outside any VRZ. Accordingly, all vessels complied with the seasonal VRZs.

By contrast, one ARK-affiliated vessel fished inside Hope Bay VRZ on 29 and 30 March 2023, catching 142.8 tonnes, in violation of the annual VRZ agreement.

Table A2-1. Synopsis of the krill fishing season 2022/2023 (1 December 2022 to 30 June 2023).

	Subarea 48.1	Subarea 48.2
Max No. fishing vessels	8	8
Subarea closure	16 June	NA
Total Catch (tons)	153,614.92	184,947.37
% Subarea quota	99.1%	66.3%

Table A2-2. List of krill fishing vessels operating in the 2022/23 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.

COMPANY	VESSEL NAME	Haul-by-Haul data	AIS information
PescaChile	Antarctic Endeavour	YES	YES
JEONG-IL	Sae In Leader	YES	YES
AKER BIOMARINE	Antarctic Sea	YES	YES
	Saga Sea	YES	YES
	Antarctic Endurance	YES	YES
DONGWON	Sejong	YES	YES
CNFC	Long Fa	NO	YES
Jiangsu Sunline Deep Sea Fishery Co.*[A]	Shen Lan	NO	YES
IKF Ltd.*	More Sodruzhestva	NO	YES

*Not an ARK member

[A] Jiangsu Sunline joined ARK in July 2023.

Table A2-3. Krill catches obtained inside and outside of the VRZs during Summer (Dec-Feb) and Winter (Mar-June) of the 2022/23 season (source: ARK database).

	Summer (ton)	Winter (ton)
Inside VRZs	0	47,742.0
Inside Hope Bay VRZ	0	142.8
Outside VRZs	3.6	75,963.3
Subtotal	3.6	123,848.1
ARK dataset/total catch	*100%*	*80.6%*

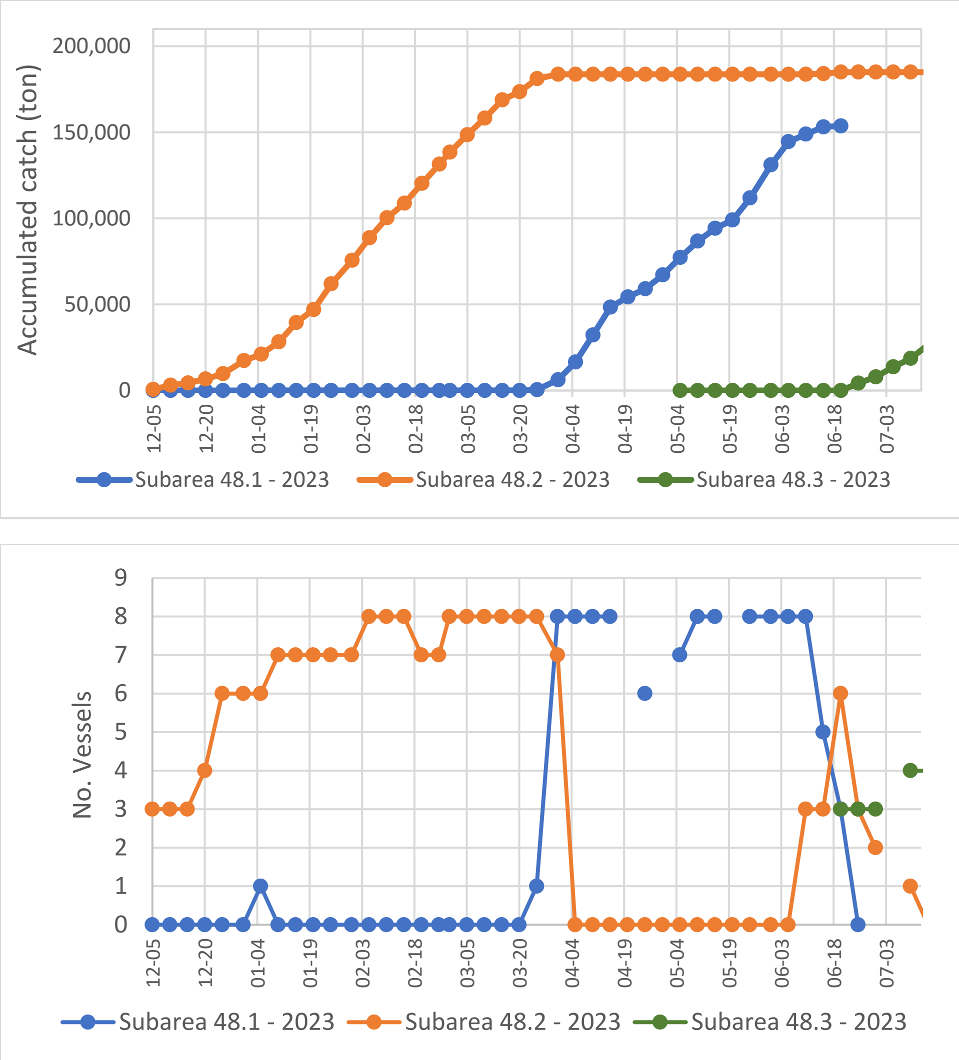
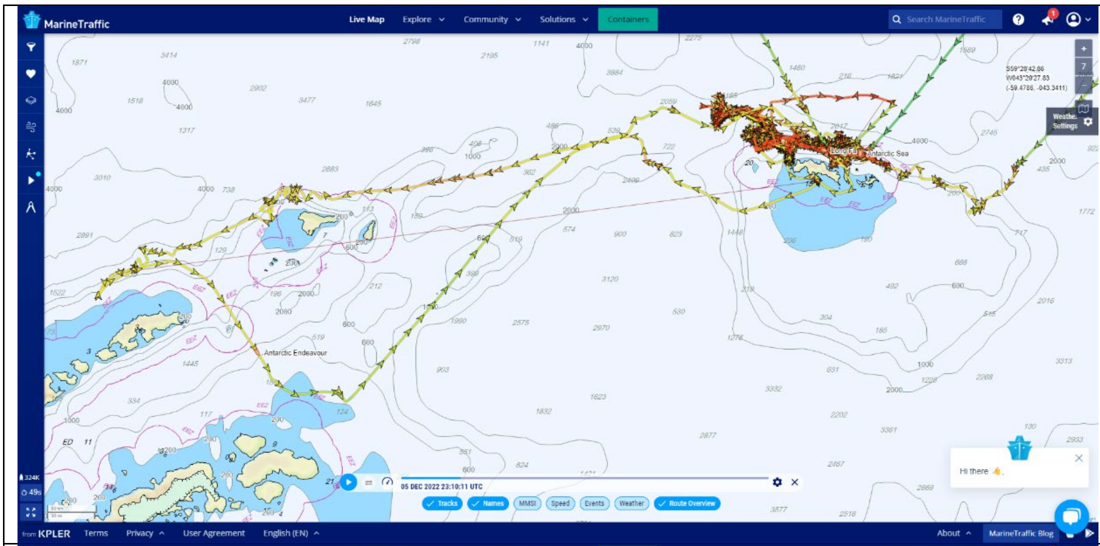
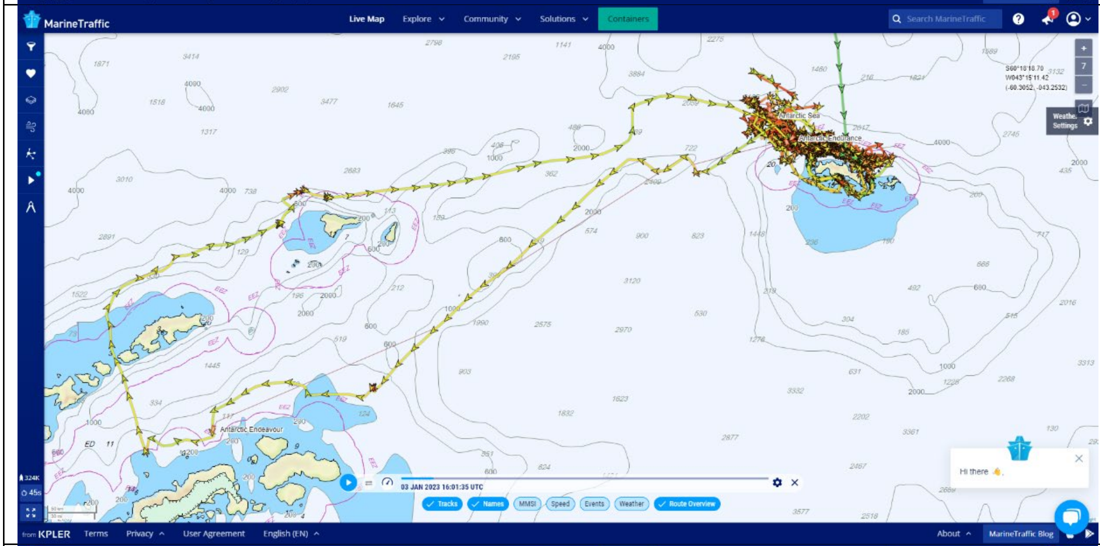


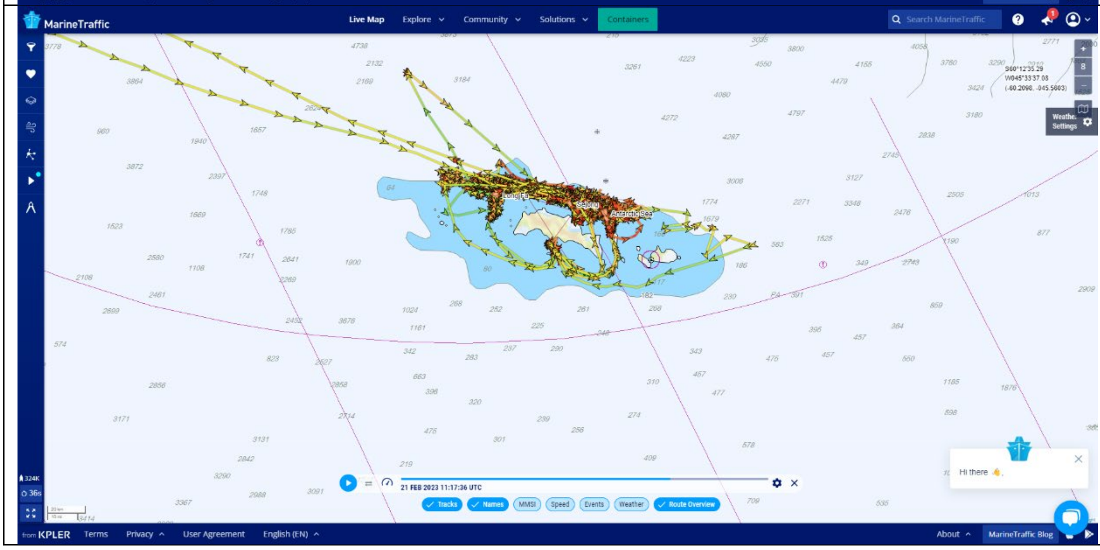
Figure A2-1. Accumulated krill catches (*top*) and the number of fishing vessels operating (*bottom*) as reported by CCAMLR.



December

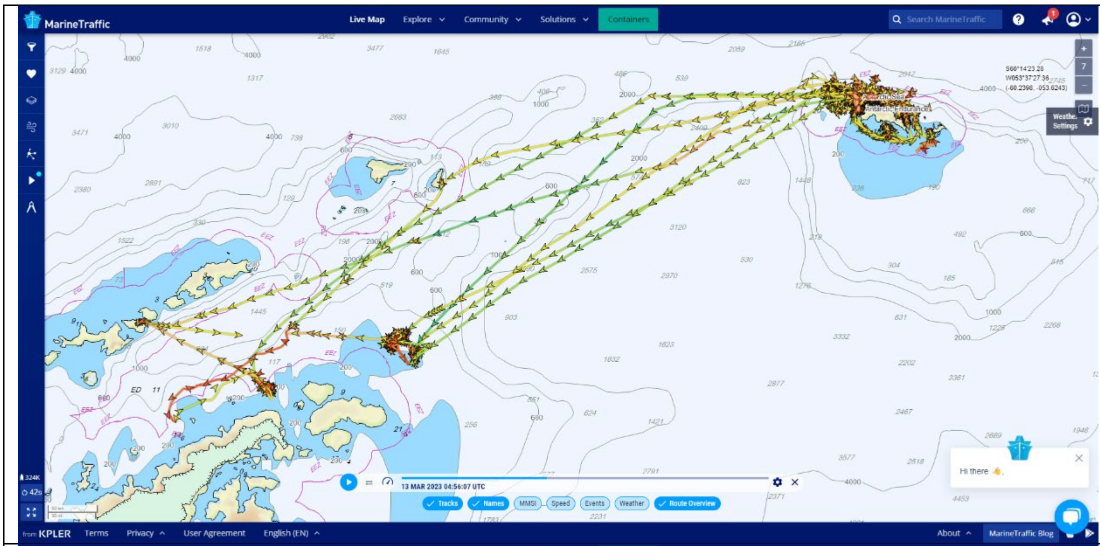
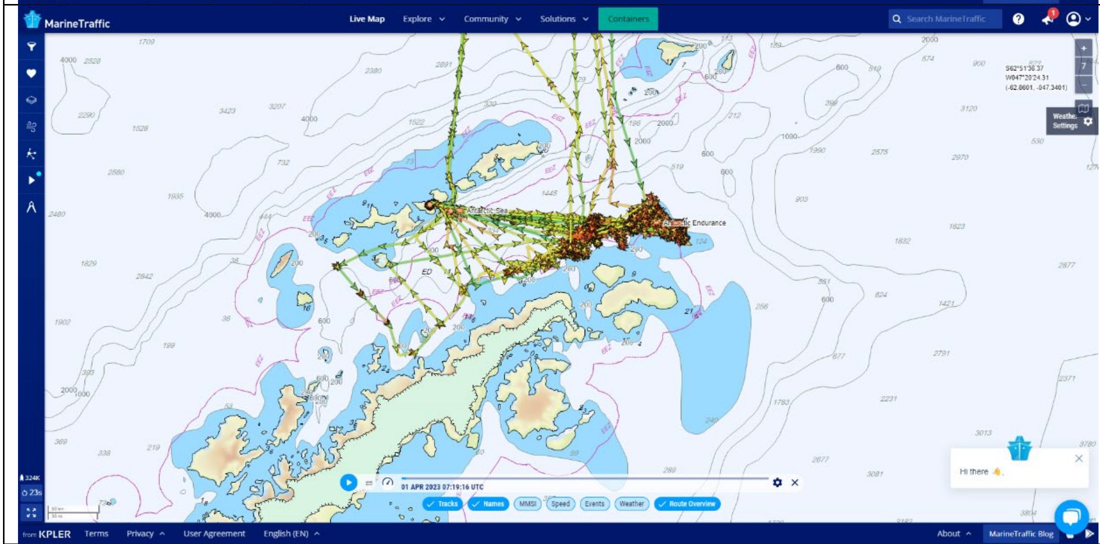


January



February

Figure A2-2. Distribution of the krill fishing fleet during the austral summer period (1 December 2022 to 28 February 2023), as obtained from MarineTraffic.com.

	March
	April
	May

June

Figure A2-3. Distribution of the krill fishing fleet during the austral winter period (1 March to 30 June 2023), as obtained from MarineTraffic.com.

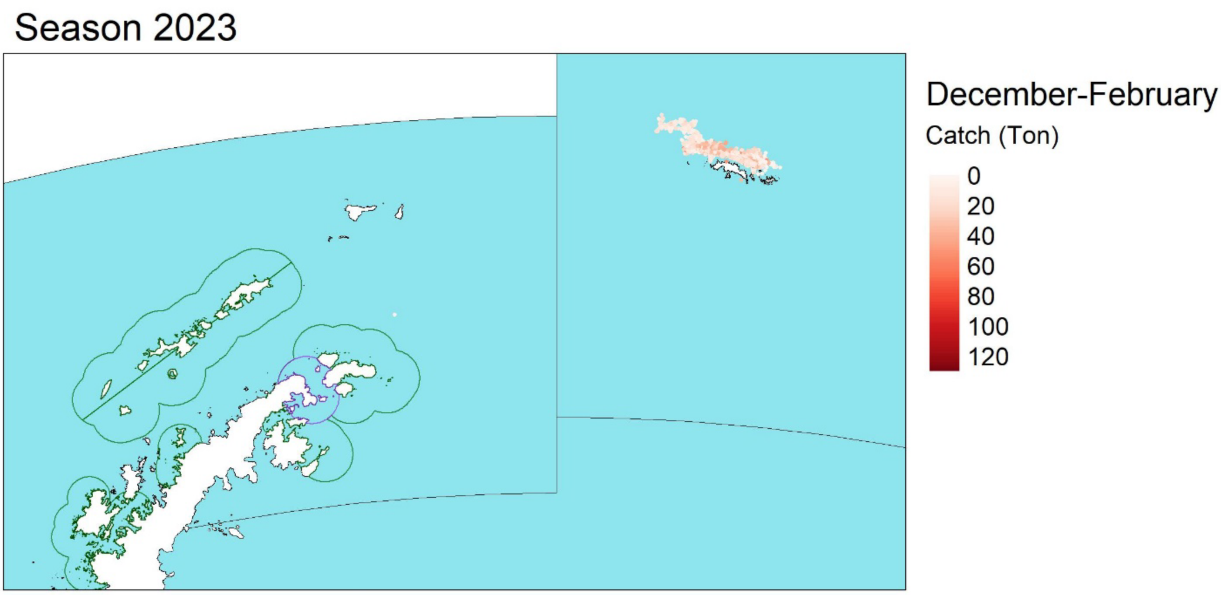


Figure A2-4. Distribution of accumulative krill catches of 6 ARK vessels during the austral summer of the 2022/23 fishing season (see Table A2-2 for a list of vessels). Source: ARK database.

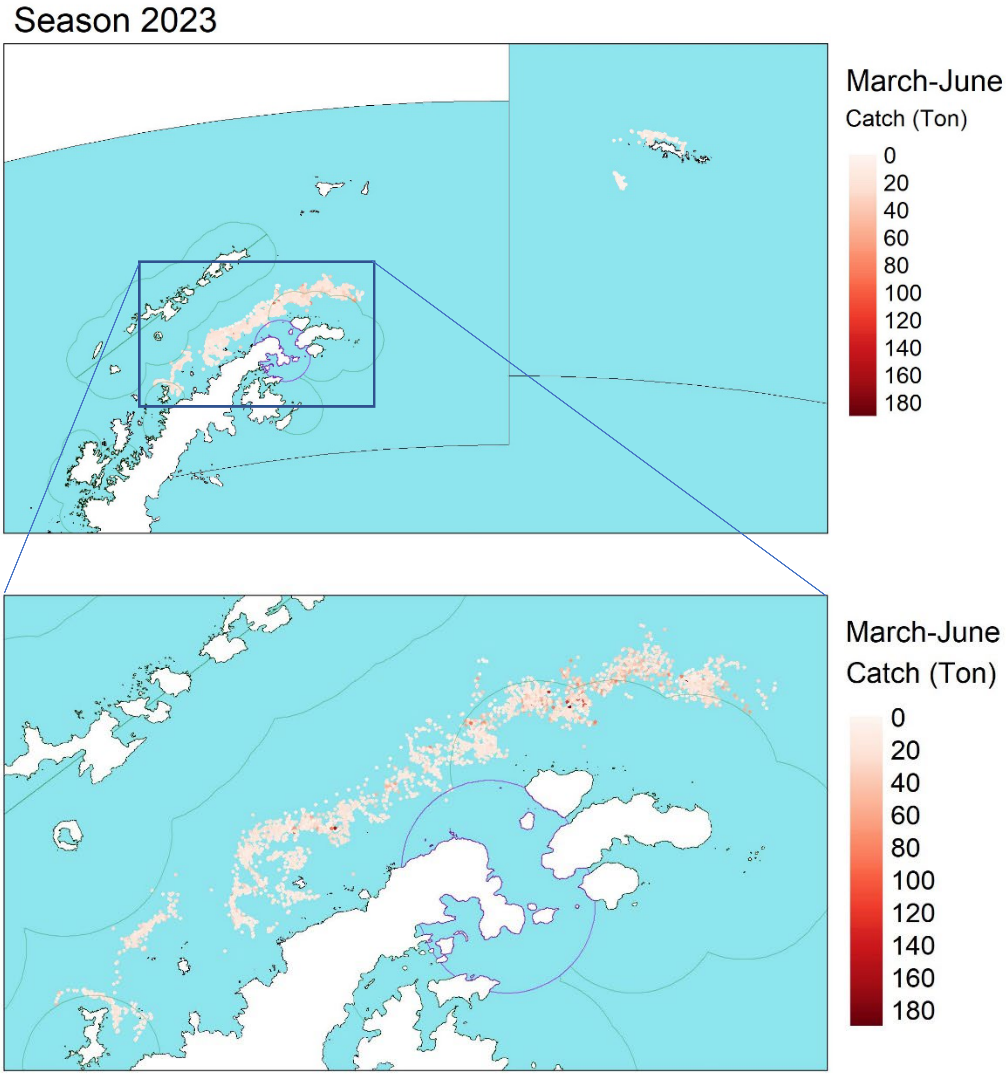


Figure A2-5. Distribution of accumulative krill catches of 6 ARK vessels during austral winter of the 2022/23 fishing season (see Table A2-2 for a list of vessels). Source: ARK database.

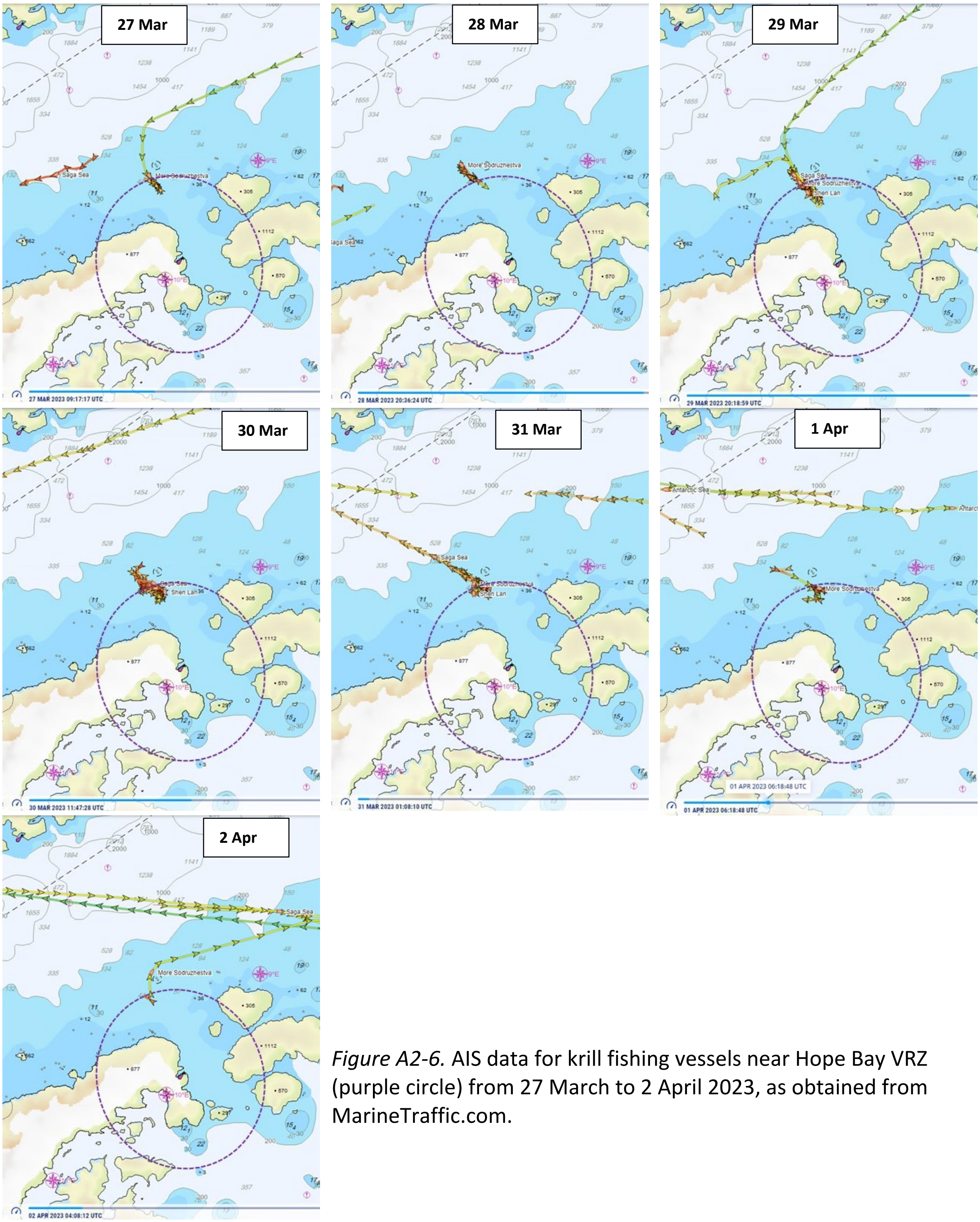


Figure A2-6. AIS data for krill fishing vessels near Hope Bay VRZ (purple circle) from 27 March to 2 April 2023, as obtained from MarineTraffic.com.

ANNEX 3. Boilerplate text stating the history, key tasks and limitations of the EP, to be included in each successive annual report.

(Highlighted text refers to the current situation and might need updating in future reports).

The ARK Voluntary Restricted Zones (VRZs) were established through negotiation between fishing companies and nongovernmental organisations in 2018. The stated goal was to "get an MPA in Domain 1 adopted by the CCAMLR Commission[2], recognizing the industry's role in contributing to the long term ambition for a large scale network of MPAs in the Antarctic Ocean." [3] There is no statement of how the VRZs will be used to achieve this goal. Furthermore there is no documentation of any scientific rationale for the VRZs. Similarly, there is no statement of the conservation objectives of the VRZs and no documented process for assessing their effectiveness.

Nonetheless, the VRZs reflect the known foraging ranges of various penguin species and the summer exclusion period covers the penguin chick rearing period. The VRZs are broadly similar to other measures that restrict krill fishing close to land. These measures include (i) CCAMLR's Conservation Measure 51-04 governing exploratory krill fisheries. This states that "no more than 75% of the catch limit shall be taken within 60 n miles of known breeding colonies of land-based krill-dependent predators"[4], and (ii) the South Georgia and South Sandwich Islands no take zones, which extend 30 km and 50 km from the shore respectively[5].

The siting of the VRZs reflects widespread support for limiting krill fishing close to colonies of land-based predators (especially penguins). This siting prioritises protection of the life-stages of land-based predators that rely on foraging close to shore over the wider suite of life-stages and species that might be affected by krill fishing. Despite this, some penguin colonies, including those on Elephant Island and in parts of the Bransfield Strait are not "protected" by VRZs. The Expert Panel (EP) was established in 2019, after the implementation of the VRZs, to provide advice to a Review Panel (RP) conducting annual reviews of the VRZs. The purpose of this review is stated in the ARK commitment document[6] and the Terms of Reference (TORs) of the EP are stated in its first annual report[7]. The EP has provided feedback on these TORs[5]. The purpose of the current text is to summarise the structure and working method of EP and clarify the scope of its contribution to annual reviews.

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[2] The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) aims to develop a representative system of Marine Protected Areas (MPAs) in the Southern Ocean. To facilitate this process, CCAMLR scientists have divided the Southern Ocean into smaller "planning domains". Domain 1 covers Subareas 48.1 and 48.2: The areas to the north and west of the Antarctic Peninsula and around the South Orkney Islands. Information about a proposed MPA in Domain 1 is available here: https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2020/10/the-need-for-a-network-of-marine-protected-areas-in-the-southern-ocean

[3] https://static1.squarespace.com/static/5df7d7d764f21960e325dbb4/t/6082e32150166565277327a5/1619190562009/ARK+Commitment+rev+DEC+2020.pdf

[4] https://cm.ccamlr.org/en/measure-51-04-2020

[5] https://www.gov.gs/32110-2/

[6] https://static1.squarespace.com/static/5df7d7d764f21960e325dbb4/t/6082e32150166565277327a5/1619190562009/ARK+Commitment+rev+DEC+2020.pdf

[7] https://static1.squarespace.com/static/5df7d7d764f21960e325dbb4/t/5ebdab58072e9456916ffd30/1589488475129/EP+Report+2019+Executive+Summary.pdf

The EP currently consists of seven members whose combined expertise covers Antarctic krill and some of its predators (especially penguins and baleen whales) as well as CCAMLR and its approach to conservation. The members include a Chair and a Secretary. The Chair's role is to lead the work of the EP and present its annual report to the RP. The Chair is elected by members of the panel to serve a three-year term. The ARK Executive Officer serves as Secretary, a role that includes organising and minuting meetings. With the exception of the ARK Executive Officer, the members of the EP provide their input on a voluntary basis. Replacement members will be selected by serving members of the EP when necessary.

EP members are not provided with any additional resources to help in their work and the only data which has been supplied to date concerns the fishing locations and catches of most ARK member vessels. The limited time and resources available to the EP and the lack of documentation about the rationale for the VRZs constrains the scope of the advice that the EP can realistically provide. In particular, the EP is not able to establish the "conservation benefits" of the VRZs or provide a retrospective scientific rationale for them. The EP has, however, provided advice on the steps that would be necessary to define conservation objectives and monitor performance relative to these objectives[5,8]. Equally the EP cannot advise on "operational challenges" in complying with the VRZs.

The EP is able to contribute to the annual review process in the following ways:

(1) Analyse catch data to assess compliance with the VRZs.

(2) Report briefly on new data and research on the status of Antarctic krill and its predators in Subareas 48.1 and 48.2.

(3) Report briefly on developments in krill fishery management and ecosystem protection affecting Subareas 48.1 and 48.2.

(4) Provide expert opinion in response to clear requests from the RP.

(5) Provide advice on how the RP can progress its objectives when these are beyond the current capacity of the EP.

(6) Provide additional information or advice which the EP considers relevant to the work of the RP.

The delivery of these contributions will depend on the availability of relevant data. Under the current arrangements contribution 1 (compliance) is the only part of the annual review process for which the EP expects to perform any new quantitative analysis. Expert opinion will be provided with the general caveat that opinions are subjective.

[8]https://static1.squarespace.com/static/5df7d7d764f21960e325dbb4/t/605b8eafa44ec4206c7c2e4e/1616613039712/Report+Expert+Panel+2020+wvf.pdf