CCAMLR

Commission for the Conservation of Antarctic Marine Living Resources
Commission pour la conservation de la faune et la flore marines de l'Antarctique
Комиссия по сохранению морских живых ресурсов Антарктики
Comisión para la Conservación de los Recursos Vivos Marinos Antárticos

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Evaluating the economics of the Antarctic krill fishery

Submitted by ASOC

EN

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Abstract

CCAMLR must act to conserve Antarctic marine living resources and the Antarctic ecosystem, using the best scientific evidence available. The Antarctic krill fishery has dramatically increased in recent years to more than two-thirds of the trigger level in Area 48, with concerns by most Members that catches at these levels if taken from small areas could impact krill predators. Recent CCAMLR meetings have indicated that the current scientific information on Antarctic krill, the krill-based food web and the fishery is insufficient for some Members to agree to spatial management measures influencing the spatial distribution of krill catch. Critically, the availability of scientific information is dependent on funding scientific activities that are relevant to the decisions being made. This should be part of the cost of managing a fishery. In recent decades, the economics of fisheries has come under the spotlight, particularly in relation to whether those benefitting from the fisheries are making reasonable contributions to their management. In this paper, we assess the economics of the Antarctic krill fishery, the beneficiaries of the fishery, and the costs of producing the scientific information currently available. From this analysis, we recommend that the Commission agrees on a management strategy for which the research needs are identified, costed and implemented, and to which the Commission can commit to fulfilling.

Introduction

The CAMLR Commission has an obligation under the CAMLR Convention to put in place management measures to achieve the Convention's objectives based on the evidence available and to facilitate research into Antarctic living marine resources and the marine ecosystem to provide the evidence to feed into management decision making.

Antarctic krill (*Euphausia superba*) is a target species for fishing vessels from Chile, China, Korea, Norway, and Ukraine, which caught a total of almost 450 000 tonnes in the 2019/2020 fishing season. The krill fishing sector generates value and creates employment (not just in the catching sector, but also in downstream processing and marketing) through various products derived from the catches. Antarctic krill is the key species in the food chain in the Southern Ocean for animals such as whales, penguins, flying seabirds, seals and fish, for which krill make up the largest part of their diet. For this reason, krill are considered a keystone species in the Southern Ocean ecosystem. They also play an important biochemical role in transporting and transforming essential nutrients, stimulating primary productivity, and influencing the carbon sink.[2]

Key krill-related Conservation Measures (CMs) related to precautionary catch limits, exploratory fishing, and scientific observation include Conservation Measure 51-01 through Conservation Measure 51-07, the latter perhaps being the most important with its focus on Statistical Subareas 48.1, 48.2, 48.3 and 48.4 given that these are the sub-areas where most krill fishing takes place[3]. CM 51-07 is due to expire in 2021, and in 2019 the Scientific Committee and Commission[4] endorsed the krill work plan to progress the 'preferred management strategy', or system, by 2021 when CM 51-07 expires. Despite there being an agreed science plan for krill, existing CMs do not constitute an ecosystem-based management strategy for krill and the Commission has not so far agreed a strategy for krill. In particular, the Commission has not yet identified how it would ensure the conservation of the krill-based foodweb as the krill fishery expands, a requirement of Article II of the Convention.

[1] This paper was prepared by Poseidon Aquatic Resource Management Limited, on behalf of ASOC, and contains the results of their research and analysis. For ASOC's policy positions on the management of the krill fishery, see CCAMLR-40/BG/10, *Moving forward, not backward, with krill fishery management*.
[2] Cavan et al, 2019. The importance of Antarctic krill in biogeochemical cycles | Nature Communications
[3] Other areas have historically been the focus of fishing activity and may become so again in the future
[4] SC-CAMLR-38 2019

In 2011 when the krill catch was at a relatively low level, the Scientific Committee identified that, as the fishery expands towards the trigger level, the need for a reliable and statistically powerful field monitoring program would need to be in place. This requirement means that krill-related research now needs to be considerably greater than what was then in place to:

- inform the revision/replacement of CM 51-07;
- evaluate other CMs in the future, as the basis for any expanded fishing effort in areas 58.4.1-2;
- ensure an ecosystems-based approach to fisheries management which safeguards predator species; and
- provide the basis for a sustainable commercial fishery.

At present, there are no costed estimates for future agreed research requirements, no available documentation on current levels of funding for krill-related research, and except for CCAMLR-related income from member's fixed contributions and income based on catch tonnage, no agreement on who should pay for research and on what basis. A sustainable system for funding research to provide the necessary evidence to support an agreed management strategy for krill is thus lacking. This absence of information on the economics of the fishery and its management system means that there is no clear understanding of whether the fishery can be managed in such a way as to achieve the objective in Article II, while ensuring the economic costs of managing the fishery are reasonable given the value of the fishery to CCAMLR Members. An important start for understanding this conundrum is what the present costs of research are compared to the present value of the fishery and how those costs are borne by Members.

This paper provides information on recent/current contributions to krill research, as well as data on vessel costs and earnings as the basis for assessing the ability of private sector companies to contribute to research costs. The potential for the private sector to contribute to research in the future is likely to be impacted by sector and market trends, which are also considered, along with the implications of these trends on the potential future need for research. The paper also makes proposals for progressing towards a more sustainable basis for funding krill-related research required as part of an agreed management strategy, recognising that outside of the funds provided to CCAMLR (some of which are used for krill-related research), investments in research will remain voluntary.

Current research expenditure

The four main existing sources of funding for krill-related research activities are: i) the private sector; ii) national governments on national research activities; iii) philanthropic/charitable organisations; and iv) CCAMLR funds. Typical annual expenditure on krill-related research activities by each source is presented below, based on data available over the past three to five years.

Private sector fishing companies contribute to research in five ways:[5]

i. Covering the daily cost of running fishing vessels when tasked for research as part of national Antarctic research programmes, periodic surveys such as the 2019 large scale krill survey, and annual transects organised by the Association of Responsible Krill-harvesting-companies (ARK). Depending on the vessel used, daily operating costs are US$ 25-45,000/day. On an annual basis, typical average costs paid for by fishing companies are estimated at US$ 1.3 million.
ii. Paying for salaries, flights, insurance, onboard subsistence, and management of observers deployed on fishing vessels. Based on average daily costs/per observer and the number of observer days, annual costs to the private sector are c.a. US$ 600 000.
iii. Ad hoc funding of national scientists and research projects, estimated at US$ 30 000 per year.
iv. Funding of the Antarctic Wildlife Research (AWR) fund[6], which supports krill-related research projects to the tune of US$ 200 000 per year.

[5] Data collected by Poseidon Aquatic Resource Management Limited, through a survey of private sector companies completed March – May 2021, and as provided by ARK
[6] Provided by Aker Biomarine

v. Provision of funding for ARK. When considering an appropriate proportion of secretariat-related costs and those of krill-related research and meetings organised and paid for by ARK through funds provided by its private sector members, annual costs to the private sector are c.a. US$ 40 000.

Total typical contributions by private sector fishing companies to krill-related research activities are thus estimated to be c.a. US$ 2 million per year.

Several *national governments* fund krill-related research through ship-based Antarctic surveys and through funding for krill-related projects and researchers/scientists in national institutes. These activities are not part of the CCAMLR budget (considered below) but contribute to work on CCMALR issues. Countries funding krill-related activities include Argentina, Australia, China, Chile, Germany, Norway, Russia, Ukraine, the UK, and the USA. For countries funding ship-based surveys in the Antarctic, which include krill-specific cruises, running costs of such vessels can exceed US$ 75 000 per day. Obtaining accurate and complete data on national funding for krill-related research has not been possible for all ten countries,[7] but based on data provided by some countries or available from publicly available sources, average annual funding on krill-related research for five countries in recent years has totalled US$ 10.3 million. Additionally, not included in this figure of US$ 10.3 million is the cost of the CCAMLR Ecosystem Monitoring Program (CEMP) established in 1986 to monitor the krill-based ecosystem, which focusses strongly on research related to krill predators. To date, no data from CEMP have been used for management, but the requirements for CEMP were specified with the view that they would be used in a krill fishery management system (e.g. SC-CAMLR, 2011).

Philanthropic/charitable organisations have also funded krill-related research projects and/or the activities of krill scientists, such as The Pew Charitable Trusts and WWF. Based on data available, funding of krill-related (rather than predator-specific) activities in the form of projects, and support to scientists for travel, preparation of scientific papers, modelling, and survey work have averaged more than US$ 360 000 per year in recent years.[8]

CCAMLR has a limited budget derived from annual contributions by its Members (AU$ 129,794 per Member in 2019) along with additional contributions from Members based on their annual catches (13% of Members' contributions per 100,000 units where the units for krill are 10 000 tonnes), as well as extra contributions by Members to support different activities of the Commission. Most work on CCAMLR issues is undertaken by Members and is not considered part of the CCAMLR budget. In the absence of any data on funding for CCAMLR Working Group-specific activities[9], or specific funding from the CCMALR budget allocated to specific topics, the content of Scientific Committee annual reports and the number of pages devoted to different topics can be used as an indicator of the attention given by the Scientific Committee to different issues and of how the resources of the Commission are partitioned in the CCAMLR budget. This allows for an estimate of the amount of the CCAMLR budget spent on krill-related activities[10] to be derived (see Annex for more information). Given the average annual CCMALR budget of AU$ 5.15 million over 2016-2019 (US$ 3.6 million at mid-2019 exchange rates)[11], 13% or an average of c.a. US$ 475 000 can be apportioned to krill-related activities. Additionally, it can be calculated that 18% of average annual CCAMLR expenditure for the period 2016-2019 was funded by fees on krill catches and 2% by catches on Patagonian toothfish in established fisheries, but 0% on catches in 'exploratory fisheries' for Antarctic toothfish and some Patagonian toothfish stocks (as charges are not levied on them).

[7] Contacts in each country were approached during March – May 2021 for data on funding. Two countries provided no response, while two others declined to provide data.
[8] Based on data provided by some, but not all organisations
[9] Such as for the WG-EMM
[10] while the activities were primarily related to supporting scientific activities, it was not possible to differentiate specific management functions, such as managing catch reporting, from publicly available information
[11] CCAMLR-2019, Annex 7, Appendix III

Combining the estimates from the different sources articulated above (private sector, national governments, philanthropic organisations, and CCAMLR), we estimate that on average more than US$ 13 million is spent each year funding krill-related research activities. This figure includes only some national programme and philanthropic funding, and excludes CEMP costs and the costs of hosting and participating in relevant meetings such as those of the WG-EMM[12].

Krill vessel economics and fleet trends

There is very little published information on the economics of the krill fishery. Based on engagement with the krill fishing industry to produce an estimate of cost and earnings across the fleet[13], the first sale value (i.e. sale revenues) for the combined fleet of 9 vessels operating in 2019 is estimated at US$ 223 million, with total onboard employment being in the order of 800 people. Additional shore-based employment is created by the catching sector in onshore management functions, and in downstream processing and marketing. The total global market for the two main krill products (meal and oil) was valued at US$435 million in 2019. When other krill products (e.g. frozen, dried and krill meat) are included, the likely total annual sales value is around half a billion US dollars. This illustrates the significant value created by processors and other operators along krill supply chains.

Gross operating profits[14]for the catching sector in 2019 are estimated at US$ 152 million (68% of turnover), with net operating profits[15]of US$ 69 million (31% of revenue). These figures indicate good operational profitability when compared to other fleets[16]. Net operating profit varies more substantially across the krill fleet than gross operating profits as net operating profit accounts for the cost of the main asset, the vessel. The average age of the active vessels in 2019 was 32 years old, but this ranged from a relatively young Norwegian fleet (22 years) to a relatively old Chinese and Korean fleet (38 and 37 respectively). This age disparity contributes to the variation in operating profits, as newer vessels are more efficient in terms of fuel consumption, but also net profits due to the way in which companies account for depreciation of vessel assets. Indeed, the generally positive economic performance of the fleet at present is strongly driven by the typically old age of vessels and therefore low yearly depreciation figures in vessel operating accounts.

The differing company structures across the fleet also have an influence on how a vessel operates and therefore its operating costs. Being able to fish as efficiently as possible with less down-time for supplies and transhipments (by being able to co-ordinate with your own company vessels) and less changing between fishing areas aids profitability.

Vessel operators also receive different levels of government support and benefit from different forms of subsidy, which improves profitability and facilitates re-investment in the fleet. Chile and Ukraine report very limited direct government support; Norwegian companies report no direct subsidies but enjoy high levels of indirect support from the government and from the banking sector to enable investment; and Chinese and Korean companies benefit from direct subsidies that reduce the cost of inputs such as fuel and vessel construction. For Chinese operators, the government provides direct and indirect subsidies (via policy banks) that may cover up to 60 percent of the costs associated with the construction or renovation of vessels for Antarctic krill. In addition to the subsidies for vessel construction or renovation, subsidies for the costs associated with fuel consumption in the krill fishing industry are also critical to the operation of the fishing fleet.

With regards to future fleet developments, Rimfrost (a Norwegian company that used to be active in the krill fishery) is planning to re-enter the fishery in 2022 with a new purpose-built 120m vessel, China has three vessels under different stages of construction (with state support as indicated above), and

[12] Costs for WG-EMM meetings can be roughly estimated at US$175 000 – US$ 200 000 when considering meetings of two weeks, 60+ participants, flights, accommodation, venue hire, and subsistence

[13]By Poseidon Aquatic Resource Management Limited, March to May 2021

[14] Revenues less variable costs

[15] Revenues less variable and fixed costs (before interest and tax)

[16] E.g. European distant water fleet as reported in the STECF Annual Economic Report

Russia may also enter the fishery, with a reported plan to construct a 100m vessel (with 25% state support), capable of catching 100 000 tonnes per year.

Krill supply chains

The route to market varies depending on the product, the fishing company and the extent to which it is vertically integrated. Norwegian vessels operate in a vertically integrated company structure from catching through to production and export of consume-packaged products. Chinese and Korean fishing companies have also extended their activities beyond just fishing operations with oil extraction factories in their home ports. Chile directly exports meal to the oil extraction factories in South Korea and China. Ukraine transports frozen krill meat for further processing, mainly by a large seafood processor in Belarus, into seafood products.

Krill markets

There are numerous end markets for krill oil and meal products (mainly animal feed and human food supplements), with other niche human food and pet food markets for dried, frozen and shelled meat. Following oil extraction, meal is graded depending on the remaining oil content to enter animal feed or aquaculture feed markets. Historical growth is evident in krill markets, and the value of sales is expected to rise further over the period 2020 - 2027 by around 6.5% per year for krill meat, and 12.5% per year for oil. The share of the krill meal market comprised of 60% going to animal feed products and 40% to human health supplements, while for krill oil markets are split roughly equally between oil tablets and liquid krill oil.[17]Reported prices for the main krill meal and oil products show a consistent increase over the last five years despite substantial growth in the volume of catch. These price trends, along with the growth evident in key markets for health supplements and aquaculture feed, suggest that any future increases in total catch would likely be absorbed without a significant downturn in prices.

Discussion

When considering the amount of funding for krill research over recent years, given the estimates generated and provided above for this type of funding, annual expenditure of US$ 13 million (itself very likely to be an underestimate) is around 6% of the annual landed value of krill catches (c.a. US$ 223 million). This is comparatively high compared with other estimates of expenditure by various OECD country members on research of their local fisheries.[18] However: i) circumstances in the Antarctic are very different to those of most other fisheries, with the costs of research, cost of fishing, and the scale of the ecosystem being very much larger than anywhere else, except perhaps the Arctic; and ii) catches and sales values in 2020/2021 have increased, meaning research funding as a proportion of landed values is likely to have reduced.

Despite existing levels of funding provided, there have been relatively few krill-specific CMs agreed and no adoption of a clear management strategy. Moreover, the only data currently being used in setting CMs are from the large-scale krill surveys unrelated to the conservation of krill predators. This suggests low effectiveness in the funds spent, not only because of the low number of management decisions based on the different types, and their associated costs, of scientific research, but also because current information seems insufficient for some Members to agree to additional conservation measures.

Agreeing a management strategy, for which research and monitoring requirements could then be identified, costed, and paid for through an acceptable funding mechanism, would be in the interests of all Members. With such a strategy in place and the scientific evidence available to ensure the Convention's objectives are met, there would be greater confidence that an expanding fishery would have only a low risk of failing to meet the objectives. Potential new entrants to the krill fishery also increase the urgency of agreeing a management strategy, and could mean an increased risk of illegal,

[17] Maia Research 2021a and 2021b

[18] Previous (and now old) estimates for OECD countries (Wallis and Flaaten, 2001) suggested countries typically spend around 1.3% of the landed value of fishery catches on research, and an additional 2.6% on management

unreported and unregulated (IUU) fishing, resulting in higher costs for effective management and enforcement than the current situation.

Furthermore, there has been no evaluation of the effectiveness or efficiency of funding for krill-related research, and no specific recommendations were made by the Second Performance Review of CCAMLR[19] on ensuring value for money in research funding. Doing research is costly in a challenging environment such as the Antarctic. But given vessel day costs for nationally run Antarctic research vessels of US$75 000 - 90 000/day, compared with costs for fishing vessels of US$25 000 - 45 000/day, greater use of fishing vessels could be more cost-effective if applied to appropriate areas of research where these vessels are fit for purpose. There could also be potential for greater use of remotely operated vehicles (ROVs) and un-manned platforms in the future as cost-effective data-gathering tools. Cost-effectiveness in research funding could also potentially be enhanced through better articulation of what the key research requirements are for an agreed management strategy. The Scientific Committee could play a more active role in assessing the cost-effectiveness of research.

When considering who is paying for research, current contributions by the private sector to total research costs of US$ 2 million per year, are in the order of 1% of turnover and 3% of net operating profits. This represents less than 15% of total yearly US$ 13 million estimated as being spent on research. Healthy private sector operating profits and future market demand and prices, suggest that the private sector could make greater contributions to research costs. However, net profitability differs between krill fishing companies and varies over time depending on investment cycles. Furthermore, the predicted expansion of the krill fleet could reduce profitability levels given competition for the shared krill-resource and reduced catch per unit of effort (with more vessels fishing in the same area or vessels having to move to other areas where krill densities/catches may be lower), thereby compromising their ability to contribute to research funding.

It is also notable that within the private sector there is no transparent or agreed basis for how much different operators should pay, when, and on what basis. Some are contributing a lot more than others (in absolute terms and as a proportion of profits). Furthermore, it is observed that:

- national spend on research programmes does not relate to economic gain from the fishery: major research nations (Germany, USA, Australia, and the UK) are not fishing nations, and
- some stakeholders, such as the downstream krill processing and marketing operators, are generating revenues from krill, but (unless part of vertically integrated companies) are not contributing to any research costs.

It is striking that there is no current overall assessment of how much funding is required for research priorities and needs (in part because there is no agreed management strategy). This makes ensuring and budgeting for future funding problematic, and apart from CCAMLR-related income, all funding is voluntary and therefore potentially uncertain. Estimating future research funding requirements could mean not just an assessment of the key research activities and outputs needed for an agreed management strategy, but also recognition of trends in the industry. The trend in increasing catches getting closer to the precautionary limit of 620 000 tonnes, coupled with potential fleet expansion (in some cases supported by state subsidies), suggests the potential need for greater levels of funding on specific research topics. These topics could include expansion into new fishing areas, more robust estimates of stock size/status to determine whether the precautionary limit of 620 000 tonnes remains valid, and local measures for krill predators. However, given the voluntary nature of almost all research funding, all CCAMLR members, as well as other stakeholders, are likely to require guarantees over the effectiveness and efficiency of expenditure, if they are to commit additional funds.

[19] CCAMLR, 2017

Recommendations
Based on the key findings and discussion points above, it is recommended that:

1. The Commission should agree on a krill fishing management strategy (informed by completion of the science work plan) for which future research needs can then be identified and costed.

2. Future funding needs for krill-related research should then be costed over the near- to medium-term (5-10 years), based on key research requirements of the agreed management strategy and an assessment of the efficacy and efficiency of that funding.

3. Recognising the voluntary nature of most research funding, a strategy should be specified commensurate with the agreed management strategy, to serve as the basis for research funding commitments to be made by different stakeholder groups, and the mechanisms and basis on which they would do so. The strategy, intended to place research funding on a more sustainable basis, should include not just those currently funding research activities, but should also think creatively about the potential to obtain funding commitments from organisations or sources currently not contributing.

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Annex 1: Expenditure by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) on different categories of attention[20]

1. Introduction

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) aims to achieve its objective of conservation and sustainable fisheries based on the best scientific evidence available. This evidence is provided by the Scientific Committee (SC-CAMLR) through its annual reports, which, over time, forms the body of evidence drawn upon by CCAMLR. The Commission has a limited budget according to annual contributions from Members along with additional contributions from Members based on their annual catches as well as extra contributions by Members to support different activities of the Commission. Most work on CCAMLR issues is undertaken by Members and is not considered part of the CCAMLR budget. Here, the proportion of the CCAMLR budget given to different issues is assessed.

The content of the annual reports are used as an indicator of the attention given to different issues by the Scientific Committee and also the means by which the resources of the Commission are partitioned in the management of the CCAMLR budget. The first part of this report aims to document the attention given to different categories (hereafter termed 'topics'). The second part examines the income to and expenditure of the CCAMLR budget. Combined, these two analyses are used to assess the proportion of the budget of CCAMLR that is dedicated to providing advice and managing the different categories of interest to the Commission. Also, the degree to which each of the topics is supported by the extra payments by Members for the fisheries catches is assessed.

2. Attention given to different topics by CCAMLR

Scientific Committee

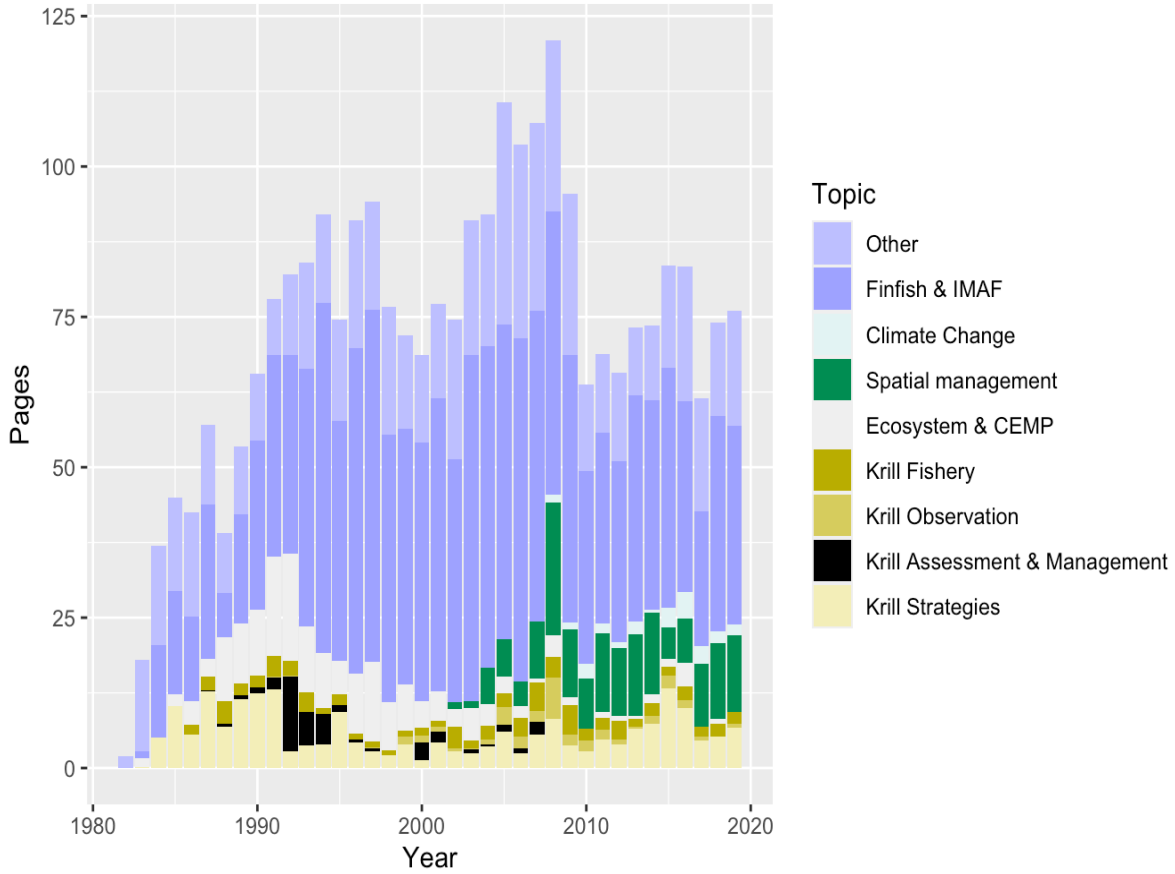
Attention of SC-CAMLR to an issue can be through its annual meeting, which has been of one week duration over most of its history, meetings of its subsidiary working groups and special workshops. SC-CAMLR has typically partitioned its business at its annual meetings according to the following topics:

- Fisheries data and management
- Scientific Observation
- Krill biology and conservation, including assessment & management advice
- Ecosystem ecology and conservation, including the CCAMLR Ecosystem Monitoring Program (CEMP), which focuses on the krill-related ecosystem, and, more recently, climate change
- Finfish biology and conservation, including assessment & management advice
- Avoidance of incidental mortality of birds and marine mammals in fisheries (IMAF)
- Spatial management, including conservation of vulnerable marine ecosystems and marine protected areas
- Administration, Cooperation with other organisations

The annual report of SC-CAMLR is not a verbatim report of meetings and workshops but summarises the issues, data, evidence and debates of importance to the Committee and the Commission. Specific advice to the Commission is highlighted. An annual tension is to keep the reports as short as possible, in plain language, in order that they are readily understandable and keep the costs of production low. Thus, the attention of the SC-CAMLR to an issue can be approximated by the number of pages of text (not including figures or tables) used to reflect the substance of and debate on the advice. While the rigours of production have changed since 1982 (the first meeting), the format has mostly stayed the same, enabling the use of text pages as an index of attention to the different topics.

[20] Prepared by Dr. Andrew J. Constable under contract to Poseidon Aquatic Resource Management Limited

Figure 1 *Pages of text on key topics of interest in the main reports of the Scientific Committee for the Conservation of Antarctic Marine Living Resources for each year from 1982 to 2019. Appendices and Annexes were not included in these tabulations.*



Success of the Scientific Committee in its provision of advice to the Commission is determined by when the advice is used to establish regulatory measures, known as Conservation Measures. The most successful period for the SC-CAMLR in advising on managing the krill fishery was in the late 1980s to early 1990s with the advent of CCAMLR's precautionary approach and establishing the means by which estimates of krill biomass could be used to establish catch limits. Assessments of precautionary catch limits and associated advice are evident in Figure 1 for Area 48 catch limits - 1991-1994, based on historical estimates of krill abundance from the BIOMASS voyages; 2000, following the CCAMLR-2000 survey; and for Area 58, following the BROKE and BROKE-West surveys of 1996 and 2006. This is despite significant periods of considerable work by the Scientific Committee.

Significant periods of work by the Scientific Committee on conserving krill and krill-dependent predators occurred as follows:

- 1980s-early 1990s - establishment and development of the CCAMLR Ecosystem Monitoring Program
- 2002-2008 - working towards developing ecosystem-based management strategies for krill fisheries in small scale management units
- 2011-2012 - working towards feedback management
- 2016-present - developing a method for distributing catch in a way to reduce risk on the krill-based ecosystem.

Alongside these developments in the last 10 years has been work to improve methods for surveying krill biomass at a local scale, including through the use of commercial fishing vessels.

None of this work has yet resulted in substantial changes to the management strategy established in the early 1990s, relying on large-scale estimates of biomass of krill to determine catch limits, despite concerns that catches less than the trigger level in Area 48 could cause local impacts on predators. Also, the decision-rule for setting the catch limit has not been confirmed to be the best rule for accommodating the needs of predators.

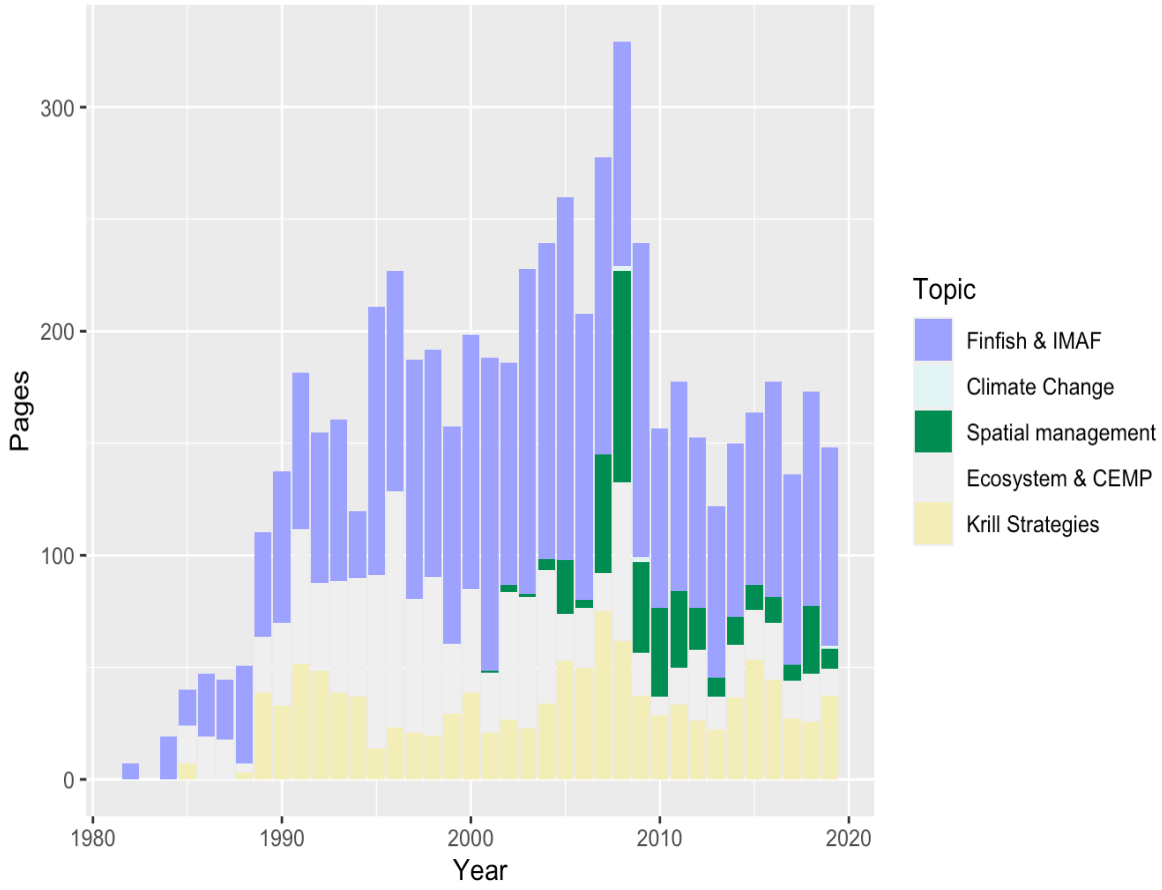
While the annual meetings of the SC-CAMLR is work undertaken in conjunction with the Commission, the intersessional work of the Scientific Committee is largely funded by Members, as the meetings and workshops are generally hosted by Members away from Hobart, except for finfish and incidental mortality meetings held at the time of the annual CCAMLR meetings. The main working groups are currently:

- Working Group on Fish Stock Assessment (WG-FSA) (held in Hobart, advising on finfish fisheries, conservation of vulnerable marine ecosystems and incidental mortality of birds and marine mammals in fisheries),
- Working Group on Statistics, Assessments and Modelling (WG-SAM) (hosted by Members, advising working groups and the Scientific Committee on methods mostly to manage finfish fisheries),
- Working Group on Ecosystem Monitoring and Management (WG-EMM) (hosted by Members with WG-SAM, advising on krill fisheries, CEMP, marine protected areas), and
- Subgroup on Acoustic Survey and Analysis Methods (SG-ASAM) (hosted by Members, advising on the design of krill surveys, including by commercial vessels).

The Secretariat supports WG-SAM and WG-EMM through the attendance of two to three staff.

The attention given to the different issues across these working groups can be reflected in the number of pages on the different topics. The following figure reflects this attention by the Working Groups, noting that all the krill topics in the annual report are included in the krill strategies here, and the spatial management topic arises from work in WG-FSA (vulnerable marine ecosystems) and WG-EMM (marine protected areas). Reports from specialist workshops are also included in these topics. Often these workshops were attended by Secretariat staff as well.

Figure 2 *Pages of text on key topics of interest in reports of Working Groups and Workshops appended to the reports the Scientific Committee for the Conservation of Antarctic Marine Living Resources for each year from 1982 to 2019.*



The Commission

The Commission has the same topics for attention as the Scientific Committee in the annual meetings, with the addition of topics that arise from the Standing Committee on Inspection and Compliance (SCIC). SCIC has the responsibility of reviewing the activities of fishing vessels and the conduct of the fisheries overall to ensure that the requirements of the conservation measures are adhered to. The attention of SCIC has been demonstrably towards the management of illegal, unregulated and unreported (IUU) toothfish fisheries, although attention in recent years has begun to include the conduct of the krill fishery. Thus, any specific budget items relating to Inspection and Compliance is considered not related to the krill fishery at present.

For the purposes of apportioning the CCAMLR budget to krill and non-krill activities, the attention to the different topics is derived from the Scientific Committee. The CCAMLR costs associated with SCIC meetings and reports, which also needs to deal with the krill fishery, are not considered here to skew the partitioning of the budget between krill and non-krill activities.

3. CCAMLR Budget

The budget of CCAMLR is reviewed annually by the Standing Committee on Administration and Finance (SCAF). Their report is annexed to the report of the Commission including a summary of the budget for the current year as well as forecast budgets.

Income

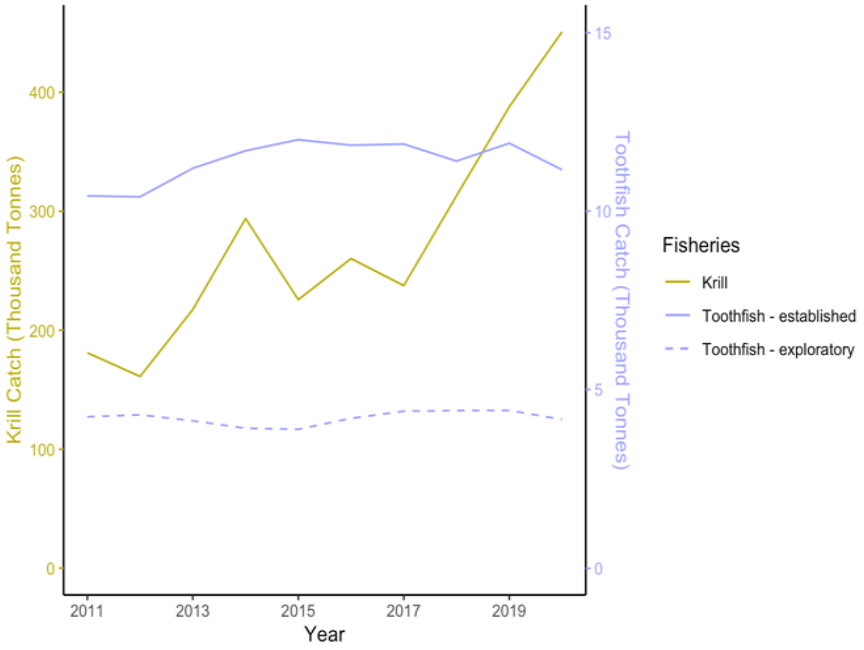
Income to CCAMLR is primarily through Members' Contributions into a General Fund. Other income to the General Fund includes fisheries notification fees that are forfeited and interest accrued on any of the CCAMLR funds. Members may contribute to Special Funds which are then managed separately.

Apportioning the income to contributions specifically related to fisheries needs to account for the formula for calculating contributions (CCAMLR-XX [2001], paragraph 3.18). Here, the contributions are analysed from 2011-2019, during which time there were 25 Members of the Commission. Each Member has a fixed contribution (in 2019 this was AU$129,794). An additional contribution is added to those Members fishing in the CCAMLR area (Members' Contributions in 2019 can be found in CCAMLR 2019, Annex 7, Appendix IV). The formula specifies that additional payments be made at the rate of 13% of Total Members' Contributions per 100,000 units (the requirements are dependent on a number of conditions in the formula), where the units for different species caught are:

- 10 tonnes of krill and/or myctophids
- 1 tonne of toothfish
- 5 tonnes of any other species

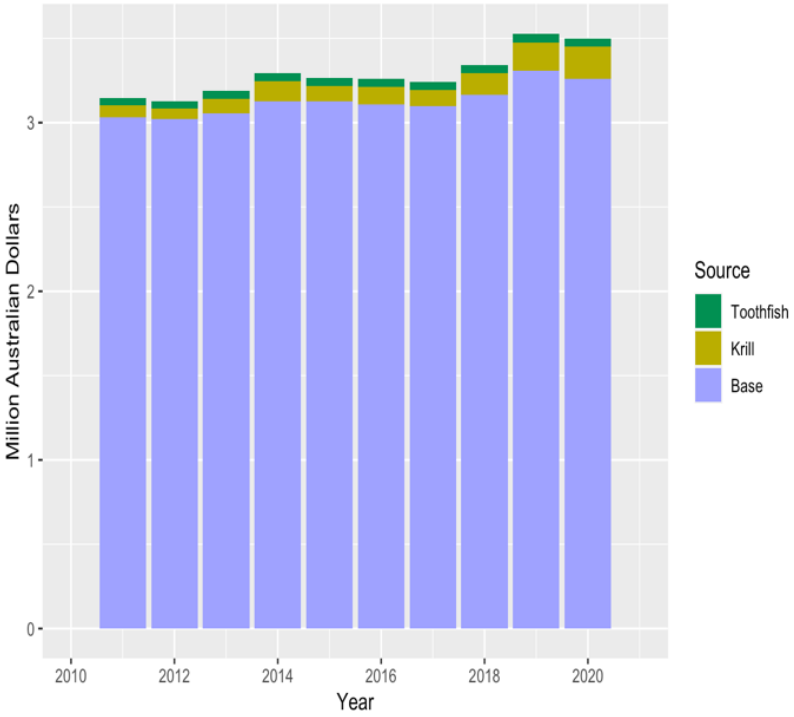
The time series of total catches of targeted krill and toothfish species for this last decade are in the following figure.

Figure 3 *Total catches in the three main fisheries in the area of the Convention for the Conservation of Antarctic Marine Living Resources for the decade 2011 to 2020.*



From available budget figures and the CCAMLR Statistical Bulletin for total catches of the different taxa, the corresponding budget is illustrated in the following figure. Note that payments for exploratory fisheries are not required, resulting in exploratory toothfish fisheries not contributing to the CCAMLR General Fund. The primary income for the CCAMLR General Fund from total Member contributions since 2011 is illustrated here.

Figure 4 *Income to the General Fund of the Commission for the Conservation of Antarctic Marine Living Resources for the period 2011-2020 derived from reports to the Standing Committee for Administration and Finance appended to the Commission report in each year. Sources of income were for Member base contributions, along with additional contributions from Members fishing for krill and toothfish. Contributions from the icefish fisheries are not included here and are negligible by comparison.*



Expenditure

The clearest representation of CCAMLR expenditure is available in the 2019 report of CCAMLR (CCAMLR-2019, Annex 7, Appendix III), based on a detailed description of the budget provided to SCAF by the Executive Secretary in 2019. It is the best representation because it includes audited figures for the preceding 3 years, an update of the budget for 2019 and a forecast budget for three years. It also includes annotations explaining the different line items. The details provided in that report are the basis for this analysis of known expenditure over the period 2016-2019.

Expenditure drawn from the General Fund relates to supporting the Secretariat and the functions of the Commission, Scientific Committee and their subsidiary bodies, through

- administration and support services by the Secretariat,
- support and servicing of meetings (CCAMLR, SC-CAMLR, Working Groups and Workshops),
- travel for supporting intersessional meetings and activities, and
- report translation and production.

Expenditure on particular tasks is through allocation to Special Funds, which are established through payments from the General Fund or through the special provision of money from Members. Many special funds are now being retired. The Special Funds that were active during the period 2016-2019 were:

- General Science Capacity (GSC) Fund
- Catch Documentation Scheme (CDS) Fund (for monitoring catches of toothfish)
- Marine Protected Area (MPA) Fund (for supporting science on spatial management)
- CCAMLR Ecosystem Monitoring Program (CEMP) Fund (for supporting some CEMP projects)

The GSC Fund has grants from the CCAMLR General Fund and can include income from other sources. Transfers to the GSC Fund from the General Fund are not included in the analysis of expenditure. The other funds have their own sources of income.

In each year, the allocation of expenditure in a given year to advice on and management of the krill fishery and other topics is determined according to the proportional attention to the topics by the Scientific Committee in that year, as described above. This proportional allocation is applied to the following expenditure:

- Total expenditure from the General Fund, less travel and the transfers to the GSC Fund and the Working Capital Fund (which is an equity fund), and
- General Science Capacity Fund.

The travel expenditure was allocated each year according to the attention of SC-CAMLR Working Group and Workshop topics on Krill Strategies, Ecosystem & CEMP, Spatial Management, and Climate Change. Finfish and IMAF were considered at WG-FSA in Hobart, requiring no travel budget. As Spatial Management covers Vulnerable Marine Ecosystems (VMEs) and Marine Protected Areas, the pages on VMEs in WG-FSA were excluded from this assessment of the budget (a total of 4.5 pages over the 4 years of expenditure).

Expenditure from the MPA Fund was allocated to the topic on Spatial Management. Expenditure from the CEMP Fund was allocated to the topic on Ecosystems and CEMP.

The outcomes of the assessment of expenditure for 2016-2019 are displayed in the following tables, noting that the "mean" of the proportions is the proportions according to the mean expenditure in Table 1.

Proportion of CCAMLR expenditure funded by catches

The proportion of expenditure funded by catches is derived from the extra Members' contributions based on their catches. The fisheries in CCAMLR contributing to the general fund are the established fisheries for Antarctic krill and Patagonian toothfish. The exploratory fisheries for Antarctic toothfish and some Patagonian toothfish stocks are not levied an extra contribution. Here, the sum of extra contributions for krill and Patagonian toothfish over the period 2016-2019 are divided by the sum of expenditure over that period for the Topics "Krill Strategies" and "Finfish & IMAF". The remaining topics are funded from the Base Contributions from Members and specific grants from Members. The results are in Table 3.

Table 1*CCAMLR Expenditure apportioned to different topics for the period 2016-2019*

	Krill Strategies	**Ecosystems & CEMP**	**Spatial Management**	**Climate Change**	**Finfish & IMAF**	**Other**
2016	813,007	325,073	412,837	242,405	1,802,742	1,201,255
2017	615,129	93,285	825,913	232,177	1,817,483	1,462,717
2018	525,515	104,470	882,290	129,743	2,419,020	1,005,508
2019	777,472	80,175	936,692	123,993	2,471,791	1,334,860
Mean	682,781	150,751	764,433	182,079	2,127,759	1,251,085

Table 2*CCAMLR Expenditure as proportions on different topics for the period 2016-2019*

	Krill Strategies	**Ecosystems & CEMP**	**Spatial Management**	**Climate Change**	**Finfish & IMAF**	**Other**
2016	0.17	0.07	0.09	0.05	0.38	0.25
2017	0.12	0.02	0.16	0.05	0.36	0.29
2018	0.10	0.02	0.17	0.03	0.48	0.20
2019	0.14	0.01	0.16	0.02	0.43	0.23
Mean	0.13	0.03	0.15	0.04	0.41	0.24

Table 3*Proportion of CCAMLR Expenditure on different topics funded by the fishery contributions to the CCAMLR General Fund for the period 2016-2019*

Krill Strategies	**Ecosystems & CEMP**	**Spatial Management**	**Climate Change**	**Finfish & IMAF**	**Other**
0.18	0	0	0	0.02	0

Annex 2: Supporting information on krill sector operators and markets[21]

Costs and earnings

There is very little published information on the economics of the krill fishery. Research completed to inform this White Paper has collated published sources and engaged with the krill fishing industry to produce an estimate of cost and earnings across the fleet. Given the commercial sensitivity of this information, results are presented in terms of the overall fishery or an average vessel across all nations based on the 2018/19 fishing season (Table 2). The ranges in the table show the variation across the fleet, which all have an influence on how a vessel operates and therefore its costs and revenues. For example, non-fishing days incur fixed operational costs, but none of the variable operational costs of fishing or the revenue gained on fishing days. However, the highest ratio of fishing days (78%) enjoyed by Chile due to its relative proximity to the fishing areas, is countered by the vessel being the smallest in the fleet in terms of length and fish hold capacity, which results in more frequent offloading of catch compared to other vessels.

Table 1: *Characteristics of an average vessel operating in the krill fishery (2019)*

Vessel characteristic	Average	Range
Age (years)	32	1 to 49
Length (metre)	108	73.5 to 134
Crew size	87	57 to 135
Fish hold capacity (m^3)	2,187	901 to 7,720
Days at sea	236	210 to 270
Fishing days	163	146 to 176
Fishing/non-fishing ratio	69%	63 to 78%
Average catch (tonnes)	40,636	20,029 to 76,753

Source: CCAMLR website and Poseidon analysis

It is important to note that the 2019 catch was 24% more than 2018, exceeding 370,000 tonnes and it grew by a further 16% in 2020 to over 450,000 tonnes, with the number of active vessels also growing from 9 to 12, illustrating the highly dynamic nature of the krill fishery and the fleet involved.

[21] Prepared by Poseidon Aquatic Resource Management Limited

Table 2: *Costs and earnings of the Antarctic krill fleet (2019)*

Total catch (tonnes)	365,727	
Average vessel production (% of LWE*)	% ex-vessel production	Average yield
Meal	79%	14%
Whole Frozen	15%	100%
Meat	6%	10%
Oil	0%	4%
Total revenue (US$ million)	223.1	
Total fleet variable costs (US$ million)	71.2	
Gross operating profit (US$ million) **	151.9	
Gross operating profit (as % of turnover)	68%	
Total fleet fixed costs (US$ million)	82.6	
Net operating profit (US$ million) ***	69.3	
Net operating profit (as % of turnover)	31%	
Average total cost per vessel per calendar day (US$)	21 680	
Average variable cost per vessel of days at sea (US$) ****	33 563	

Source: Poseidon . *Live Weight Equivalent. **gross operating profit = revenue less variable costs. *** net operating profit = revenue less variable and fixed costs of fishing (before any interest charges and tax). **** based on effort data

Gross operating profits in 2019 are estimated to average 68% of turnover with net operating profits (allowing for depreciation and other fixed costs) at 31% of revenue. This estimate of the fleet's economic performance indicates good operational profitability when compared to other fleets[22] and is at a level that would enable re-investment, however the very high capital costs for purpose-built vessels remains a major barrier to entry into the fishery.

Net operational profit varies more substantially across the fleet than gross operational profits as they account for the cost of the main asset, the vessel. The average age of the active vessels in 2019 was 32 years old, but this ranged from a relatively young Norwegian fleet (22 years) to a relatively old Chinese and Korean fleet (38 and 37 respectively). This age disparity, and the way in which companies account for depreciation of these assets, impacts the extent to which net profits are affected. Indeed, the generally positive economic performance of the fleet at present is strongly driven by the typically old age of vessels and therefore low yearly depreciation figures.

It should also be noted that different treatment of some cost items by companies impacts on the estimations provided above. For example, some companies treat labour costs as variable, while others consider them fixed on the basis that many crew are on fixed contracts and unless fishing stopped for a very long period and employees were let go, vessels would continue to be manned and thus salaries would continue to be paid.

The company structure also impacts economic performance in terms of both costs and earnings. Some krill vessels operate as individual companies that are independent from other parts of the supply chain, while others are part of a vertically integrated company which operates the fishing vessels, supply vessels and land-based processing. Operational efficiencies can be gained with greater vertical integration e.g. less fishing time is lost in linking with a company's own supply and transhipment vessels and companies with fuel bunkering capabilities can benefit from better fuel prices than independent vessels relying on 'at sea' prices for re-supplies. Company earnings are also increased through integration with land-based processing as exemplified by some Chinese fishing companies that have moved from selling frozen krill and meal to other processors, to processing krill into oil themselves[23].

[22] E.g. European distant water fleet as reported in the STECF Annual Economic Report.

[23] 青岛拥有亚洲最大远洋捕捞船昨起航远赴南极捕鱼虾 [Qingdao Has Asia's Largest DWF Vessel, Set

Subsidies

The Organisation for Economic Co-operation and Development (OECD) produce national Fishery Support Estimates to measure levels of support to the fisheries sector. These show that the level of subsidy available to different nationalities operating in the krill fishery is markedly different[24]. Chile and Ukraine report very limited direct government support; Norwegian companies report no direct subsidies but enjoy high levels of indirect support from the government and from the banking sector to enable investment; Chinese and Korean companies benefit from direct subsidies that reduce the cost of inputs such as fuel and vessel construction.

China's first Antarctic Ocean Living Resources' Development and Utilization Project was launched in 2011[25]. A 2016 China government policy states that central government will provide subsidies to cover 30 percent of the cost of building or renovating new Antarctic krill harvesting and processing vessels.[26] In addition to direct subsidies from the central government, Chinese policy banks also provide matching funds. Policy banks provide low-interest, long-term loans for the renovation and construction of DWF fishing vessels that cover up to 30 percent of the cost. In total therefore, the government provides direct and indirect subsidies (via policy banks) that may cover up to 60 percent of the costs associated with the construction or renovation of vessels for Antarctic krill. China recently has been building new, technologically advanced vessels that are capable of both harvesting and processing Antarctic krill. In addition to the subsidies for vessel construction or renovation, subsidies for the costs associated with fuel consumption in the krill harvesting industry are also critical to the operation of the fishing fleet. According to the 2016 policy mentioned above, each krill fishing vessel can receive subsidies for "the exploration and utilization of international fishery resources."

Future fleet developments

Aker Biomarine's purpose-built krill vessel, the Antarctic Endurance, which entered the fishery in 2019/20, is the first of several purpose-built krill vessels expected to enter the fishery, eventually replacing the re-purposed fishing vessels that have operated in the fishery thus far. Antarctic Endurance is a very large, long-term capital investment, which inevitably impacts net profits in the short-medium term. But it is claimed the vessel will reduce emissions [mainly through fuel savings] by 30%[27], which illustrates the efficiency improvements purpose-built vessels will bring to maintain profitability. Rimfrost, another Norwegian company that used to be active in the krill fishery, is also planning to re-enter the fishery in 2022 with a new purpose-built 120m vessel[28].

China places great importance on the krill fishing industry, aiming to develop a "second distant-water fishery industry," and accordingly has been upgrading its krill fishing fleet by designing and building new vessels (Table 3).[29] The new vessels all operate using a continuous pumping (CP) system, with their fishing capacities estimated to total at least 240,000 tons per year.

SailYesterday to Harvest Antarctic Krill], 青岛早报 [Qingdao Morning News], 27 February 2015, http://qingdao.iqilu.com/qdyaowen/2015/0227/2318049.shtml.

[24] OECD (2017) https://www.oecd-ilibrary.org/agriculture-and-food/support-to-fisheries_00287855-en

[25] https://www.seafoodsource.com/news/supply-trade/chinas-demand-for-krill-may-result-in-changes-to-ccamlr-convention

[26] 农业部办公厅 [Ministry of Agriculture General Office], 农业部办公厅关于印发远洋渔业油补政策调整实施方案的通知 (农办渔〔2016〕43号) [Ministry of Agriculture General Office Notice on the Implementation Plan for Adjusting Fuel Subsidies to Distant Water Fisheries (MOA Fisheries (2016) No. 43)], 20 July 2016, http://www.weihai.gov.cn/module/download/downfile.jsp?classid=0&filename=0c2793187c384f4eb93db5d7dd32000f.pdf.

[27] https://thefishsite.com/articles/in-for-the-krill

[28] https://nutraceuticalbusinessreview.com/news/article_page/Rimfrost_commissions_11m_green_Antarctic_krill_fishing_vessel/160430

[29] 国务院国有资产监督管理委员会, 农发集团组织船队进入南极开发渔业取得重大突破, 中国农业发展集团有限公司, 24 March 2015, http://www.sasac.gov.cn/n2588025/n2588124/c3793281/content.html.

Table 3 *New Chinese Vessels in use or in development*

name	total engine power (kW)	processing capacity (tons/day)	carrying capacity (m^3)	expected fishing capacity (tons/year)	catch system	Development stage
Shen Lan	8,000	420	6,000	80,000-100,000	continuous	Planned operation 2021/2022
Nan Ji	8,000	≥420		≥80,000	continuous	in design
Yong Li		800		80,000	continuous	in manufacture

Source: Poseidon

In addition to the expansion of fishing capacity by existing fishing nations, the Russian Fishery Agency has reported plans to re-enter the Antarctic krill fishery: "*The resumption of Russian catch of Antarctic krill and the construction of krill fishing boats are laid down in the Strategy for the Development of the Fisheries Industry by 2030. At the same time, fishers are concerned about securing the right to access the resource, since the organization of fishing requires large financial costs and is associated with high risks.*"[30] The Agency also expressed the need to act quickly, citing a risk that new conservation measures may prevent Russia re-entering the fishery. The plan is to construct a 100m vessel estimated at US$150m (with 25% state support), capable of catching 100 000t per year. This, like other future vessels may carry out further processing on board including oil extraction, which is currently restricted to land, but the necessary technology is being tested at sea[31]. This would help to minimise rising logistics costs and enable the fishing companies to add value before onward sale.

Supply chain

The different types of krill product produced by the vessels enter different supply chains, with most processing krill on board to produce dried and ground krill meal, which is then further processed on land to extract the oil (with the resulting low-oil content meal going to feed markets). Some Korean and Chinese vessels freeze the krill whole for shipment to land-based processing, while the Ukrainian vessel cooks and peels most of the catch then freeze the meat onboard for transhipment to land-based seafood processors.

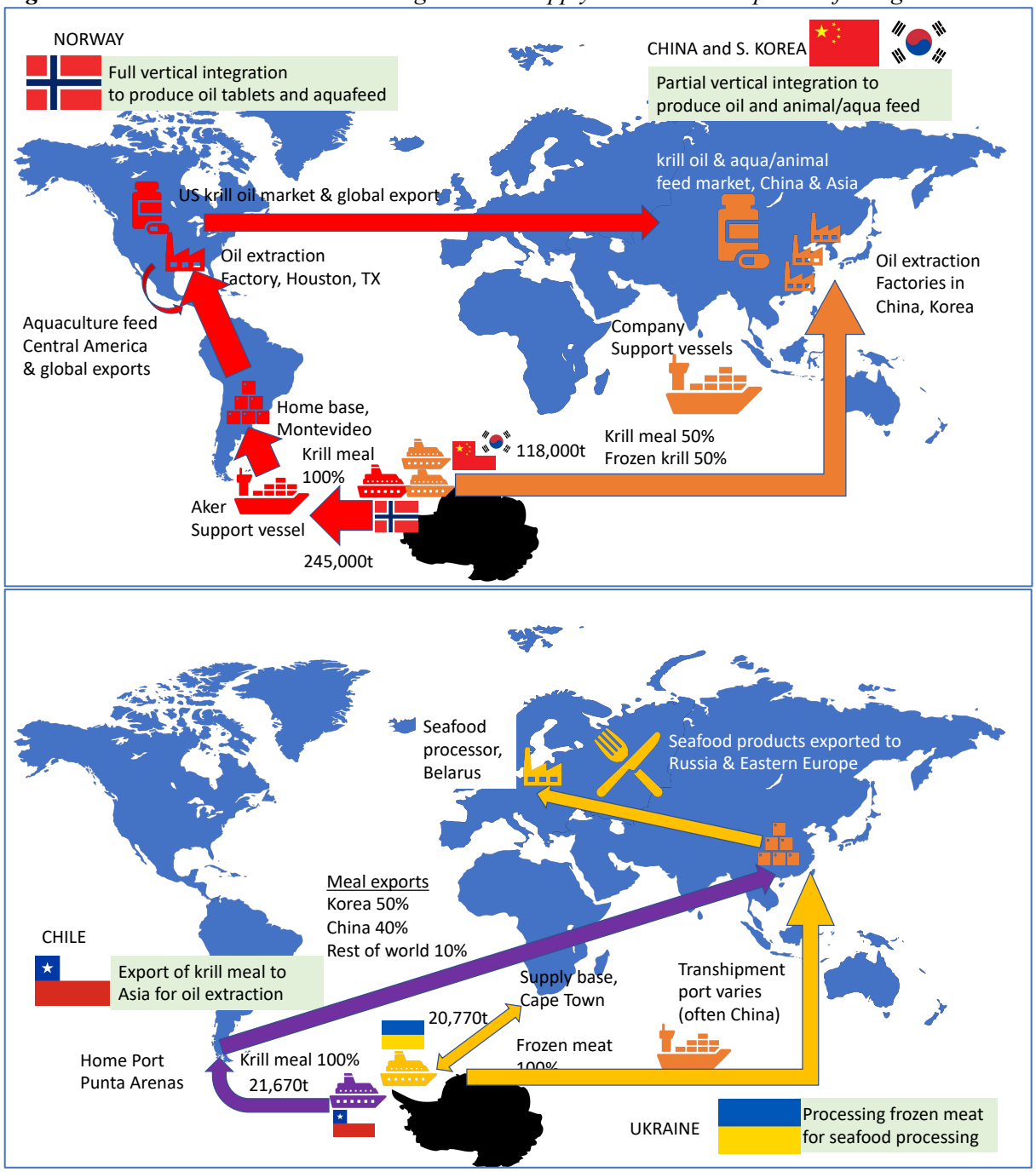
The route to market varies depending on the specific fishing company and the extent to which it is vertically integrated, as illustrated in

[30] https://fishretail.ru/news/ribakov-prizivayut-zastolbit-pravo-na-kril-420269

[31] E.g. solvent-free oil extraction technology developed by Tharos: http://www.tharos.biz/about-us/

Figure **1**. Norwegian vessels operate in a vertically integrated global supply chain, landing product to Montevideo, shipment to Texas for oil extraction and on to pharmaceutical companies for packaging out to consumer markets in the US and beyond. Chinese and Korean fishing companies have also extended beyond just fishing operations with oil extraction factories in their home ports, also supplying a range of human and pet food markets for frozen krill. Chile directly exports meal to the oil extraction factories in South Korea and China. Following oil extraction, meal is graded depending on the remaining oil content to enter animal feed or aquaculture feed markets. Ukraine transports frozen krill meat to further processing, mainly by a large seafood processor in Belarus, into seafood products.

***Figure 1** Antarctic krill global supply chains per fishing nation**



Source: Poseidon *Norway (red), China & S. Korea combined (orange), Chile (purple), Ukraine (yellow)

Markets

The global market for krill products in 2020 is estimated to total 72,000 tonnes of krill meal and 2,700 tonnes of krill oil, valued at US$ 164 million and US$ 311 million respectively (Table 4). The total volume in terms of Live Weight Equivalents (LWE) exceeds the reported total catch of Antarctic krill by 80%[32]. While there are other krill fisheries, including just over 70,000t for *E.Pacifica,* the Antarctic fishery for *E. superba* accounts for the great majority of global supply. Assuming the trade data is correct, the additional market volumes may result from some of the products being traded as krill meal or oil not composed of 100% krill and/or including packaging.

[32] Based on average reported yields of 14% for meal and 4% for oil.

Table 4. *Volume and value of global krill oil and meal markets*

Global krill oil	2019		2020			estimated 2027
US$ million	US$m	tons	US$m	tons	CAGR*	US$m
Krill oil tablet (human)	144.0	1,138	161.5	1,242	13.1%	382.9
liquid krill oil (pet/animal*)	135.8	1,357	149.1	1,481	11.9%	326.9
total oil	**279.8**	**2,495**	**310.6**	**2,723**	12.5%	**709.8**
Global krill meal	2019		2020			estimated 2027
US$ million	US$m	000 tons	US$m	000 tons	CAGR*	US$m
food grade meal	61.2	19.8	65.2	20.8	6.0%	107.5
feed grade meal	93.5	48.7	98.4	51.2	7.4%	148.3
total meal	**154.7**	**68.5**	**163.6**	**72.0**	6.6%	**255.7**

Source: MAIA Research Analysis

*market information suggests this grade can still be used for human dietary supplements

**Compound Annual Growth Rate

The main products derived from krill can be broadly categorised into meal and oil (extracted from krill meal) that enter human-consumption markets or animal feed markets. As Table 4 shows, all markets have shown strong growth, with krill oil tablets showing the strongest annual growth. In 2020 Europe accounted for around 40% of global krill oil sales, North America 33% and the Asia-Pacific region 20%[33]. All markets show strong growth, with the Asia Pacific region showing the highest growth mainly from Korean and Chinese middle-income consumers increasingly interested in health products. Chinese producers are seeking to increase the quality of oil production to human-consumption standards to supply this demand with domestic production rather than imports[34]. Although the human consumption market is the highest value, there are also high value aquaculture feed markets, such as intensive shrimp farming, in which Aker Biomarine also expects to see growth[35].

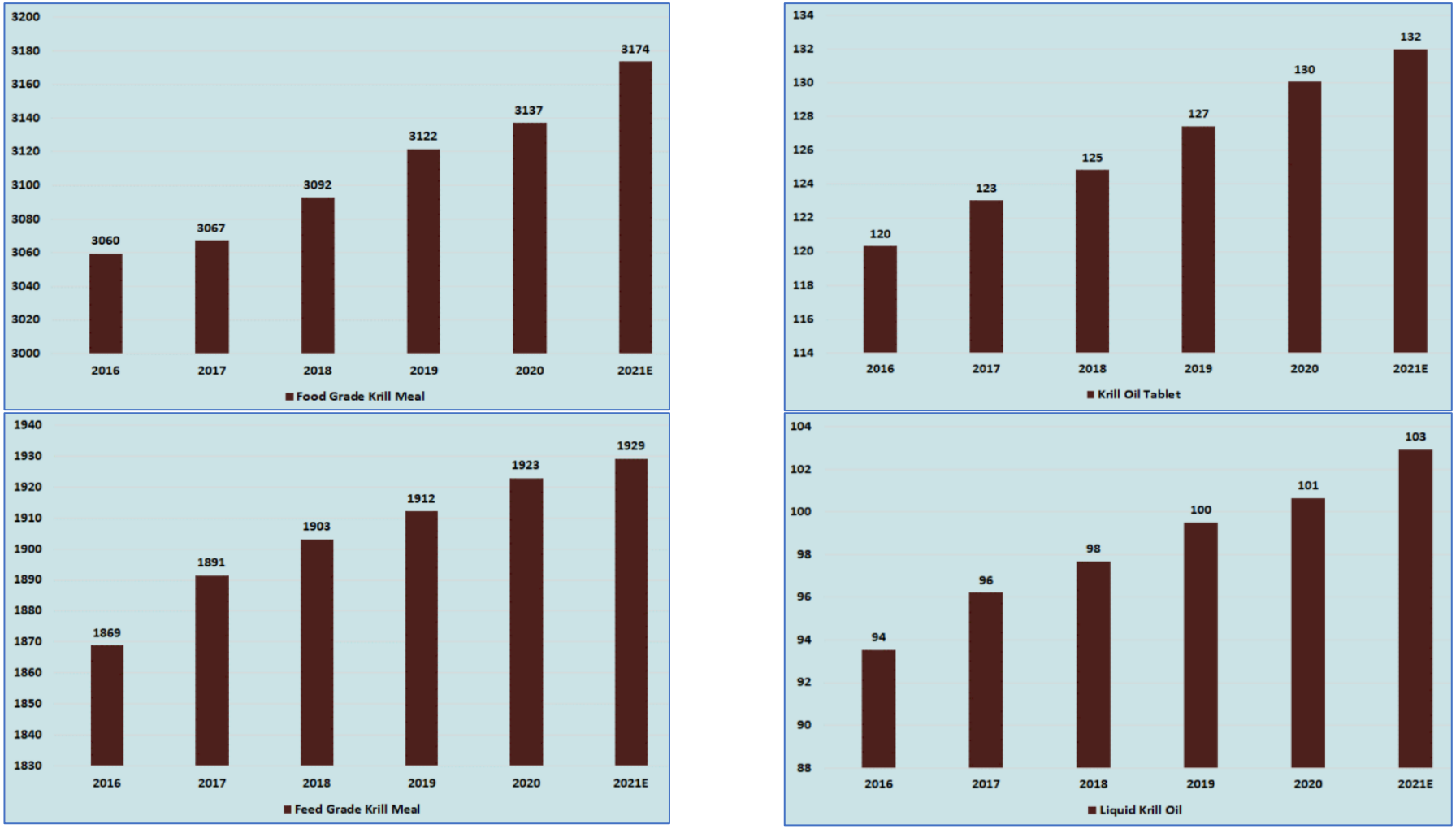
The reported prices for the main krill meal and oil products show a consistent increase over the last five years despite the substantial growth in the volume of catch (Figure 2). These price trends, along with the growth evident in key markets for health supplements and aquaculture feed, indicate that the expected increase in total catch can be absorbed without a significant downturn in prices. This bodes well for the continued profitability of the krill fishery, until the revenues of operators are significantly constrained by the amount they can catch before the Total Allowable Catch (TAC) is exhausted.

[33] MAIA Research Analysis, 2021

[34] https://www.seafoodsource.com/news/supply-trade/chinas-demand-for-krill-may-result-in-changes-to-ccamlr-convention

[35] https://thefishsite.com/articles/in-for-the-krill

Figure 2 *Price trends for krill meal in US$/tonne (food grade top left, feed grade bottom left) and oil in US$/kg (tablets top right, liquid bottom right) 2016-2021*



Source: Maia Research Analysis (2021 prices estimated)