Disclaimer: Seafood Watch strives to ensure that all our Seafood Reports and recommendations contained therein are accurate and reflect the most up-to-date evidence available at the time of publication. All our reports are peer-reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science or aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch program or their recommendations on the part of the reviewing scientists. Seafood Watch is solely responsible for the conclusions reached in this report. We always welcome additional or updated data that can be used for the next revision.
About Seafood Watch®

Monterey Bay Aquarium’s Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program’s goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program’s conservation ethic to arrive at a recommendation of “Best Choices,” “Good Alternatives” or “Avoid.” The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, our sustainability recommendations and the underlying Seafood Reports are updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.
Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished\(^1\) or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

Based on this principle, Seafood Watch has developed four sustainability criteria for evaluating wild-catch fisheries for consumers and businesses. These criteria are:

- How does fishing affect the species under assessment?
- How does the fishing affect other, target and non-target species?
- How effective is the fishery’s management?
- How does the fishing affect habitats and the stability of the ecosystem?

Each criterion includes:

- Factors to evaluate and score
- Guidelines for integrating these factors to produce a numerical score and rating

Once a rating has been assigned to each criterion, we develop an overall recommendation. Criteria ratings and the overall recommendation are color-coded to correspond to the categories on the Seafood Watch pocket guide:

**Best Choice/Green**: Are well managed and caught in ways that cause little harm to habitats or other wildlife.

**Good Alternative/Yellow**: Buy, but be aware there are concerns with how they’re caught.

**Avoid/Red**: Take a pass on these for now. These items are overfished or caught in ways that harm other marine life or the environment.

\(^1\) “Fish” is used throughout this document to refer to finfish, shellfish and other invertebrates.
Summary

Antarctic krill is targeted for the production of krill meal and oil, as well as for whole krill for human and animal consumption. Antarctic krill is patchily distributed throughout the Southern Ocean, where its aggregations are targeted with midwater trawls. This report covers Antarctic krill caught in the Bransfield Strait off the Antarctic Peninsula (CCAMLR Subarea 48.1), northwest of Coronation Island (Subarea 48.2), and to the north of South Georgia (Subarea 48.3) by Norway, China, and South Korea, and by other countries (managed under CCAMLR) that periodically fish the resource.

Antarctic krill in the Southern Ocean is currently above target biomass levels, but comprehensive biomass surveys are infrequent. Krill biomass is periodically determined from acoustic surveys, and is updated based on improvements to the techniques used to analyze acoustic survey data. Catch limits are set with the objective of preventing a decrease in the size of the population “to levels below those which ensure its stable recruitment,” and to account for the requirements of krill predators (75% escapement (CCAMLR 2015)). Catches have remained below subarea-specific catch limits intended to prevent localized depletion (CM 51-07 (CCAMLR 2014)).

Antarctic krill is managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). Part of the Antarctic Treaty System, CCAMLR is an international commission with 25 members (see CCAMLR 1980). The Scientific Committee of CCAMLR (SC-CAMLR) is responsible for collecting biomass survey data, aggregating research from CCAMLR member countries, and making a recommendation to CCAMLR, which then sets conservation measures for each subarea. The Commission has a strong track record of following scientific advice, although discrepancies between observer data and reported catches may indicate compliance issues around onboard scientific observers, and there is an ongoing effort to better understand the cause of these discrepancies. The Scientific Committee and Commission meetings have included a great deal of discussion about how to implement the CCAMLR Scheme of International Scientific Observation (SISO) in the fishery.

The impacts of the krill fishery on non-target species are unclear; reported bycatch rates differ between vessels, countries, and observer reporting practices. The information collected here is based on CCAMLR reports and expert opinion. Fur seals were periodically caught in large numbers (up to 292 within one season, according to a 2004 report) in the earlier stages of the fishery. Although reports of fur seal bycatch have declined, there were two mortalities reported in 2015, and the Commission recently amended gear regulations to require mammal exclusion devices on nets and other gear changes that should minimize mammal bycatch. Larval fish are often caught with krill, but the impact of the fishery on the adult populations of these species is unknown. Krill predators are also caught incidentally in the fishery; icefishes are the species that occur most commonly. Because tows with a higher proportion of krill by weight are more valuable, and because of CCAMLR regulations, the fishery tends to avoid bycatch.
The krill fishery has low potential impact on the physical habitat in the Southern Ocean, but the potential impacts of the fishery on the ecosystem are larger. Because krill occupies a crucial role as a forage species in the food web of the Southern Ocean, several management requirements are in place specifically to protect predators. Trigger limits are designed to prevent localized depletion; catch limits are determined by simulation and set conservatively to ensure the availability of krill for its predators. The Antarctic krill fishery is generally considered a good example of precautionary ecosystem-based fishery management (EBFM). But major uncertainties about Antarctic krill management remain. The spatial management strategy currently in place may not be sufficient for the protection of predators from local depletion. Furthermore, future developments in the fishery are likely to coincide with climatic changes that will influence krill recruitment and spatial distribution, as well as the abundance and distribution of krill predators. Climate change and the possibility of localized depletion make the future of the fishery and its ecological impact uncertain. Although fishing is not presently considered a threat to ecosystem health, there is significant uncertainty about how Antarctic krill and the predators that rely on it will fare in the future.
### Table of Conservation Concerns and Overall Recommendations

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</tbody>
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#### Scoring Guide

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

- **Best Choice/Green** = Final Score >3.2, and either Criterion 1 or Criterion 3 (or both) is Green, and no Red Criteria.

- **Good Alternative/Yellow** = Final score >2.2, and no more than one Red Criterion, and does not meet the criteria for Best Choice/Green (above)

- **Avoid/Red** = Final Score ≤2.2, or two or more Red Criteria, or Management is Critical.
Introduction

Scope of the analysis and ensuing recommendation

This report covers Antarctic krill (*Euphausia superba*) caught with midwater trawls in the Southern Ocean by countries fishing under management by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). These include Norway, China, and South Korea, as well as other countries that periodically fish this CCAMLR-managed resource. Two companies from Norway that fish for krill in the Southern Ocean are Marine Stewardship Council (MSC) certified. Because the data to distinguish bycatch and compliance between countries are not available, this report evaluates all fishing countries together, including those with MSC-certified catches.

Overview of the species and management bodies

Antarctic krill (*Euphausia superba*) is a small crustacean with a circumpolar distribution in the Southern Ocean. It lays eggs in the surface layer of the ocean, and embryos sink before they hatch, so developing larvae have to actively swim upward to reach the surface. Larvae arrive at the surface in autumn, develop during winter under the ice, and emerge as juveniles in the spring (Nicol 2006). Adult krill are found in high concentrations on shallow shelves and around islands, along the continental shelf and slope (Nicol 2006), and at the convergence of ocean currents such as the Weddell-Scotia Confluence. Krill reproduces in its second summer, and continues to reproduce annually in the summer. It has a maximum lifespan of more than 6 years (Nicol 2006), although Ikeda (1985) proposed that Antarctic krill may have a maximum lifespan of 7.5 to 11.3 years. It reaches a maximum size of 6 cm.

Genetic evidence for population structure in Antarctic krill has been inconclusive. Krill has a circumpolar distribution, with about 70% of the population residing within the 0–90° W range. The krill fishery has historically been concentrated in two areas in the Southern Ocean: a location in the Indian Ocean (Area 58), and two locations in the Southeast and Southwest Atlantic (Area 48 (Kawaguchi and Nicol 2007)). Although genetic differences between these two aggregations have been detected in the past, pairwise comparisons of samples from each aggregation have shown them to be genetically indistinguishable (Zane et al. 1998), and the most recent genomic analysis indicated no discernible genetic structuring between sites (Deagle et al. 2015). Other studies have found no genetic differences between these aggregations, and it is possible that the circumpolar movement of krill throughout its lifetime swamps any observable genetic difference (Siegel 2005).
Krill is associated with sea ice at nearly every stage of its life cycle. Krill abundance distribution and life history are strongly affected by the timing and extent of sea ice. Therefore, some of the greatest uncertainties about stock status and the appropriateness of the current management strategy concern the combined effects of fishing and climate change on krill abundance and the distribution of krill for predators.

Movement of adult krill is influenced by oceanographic conditions and behavioral aggregation patterns. The highest concentrations of Antarctic krill occur in the Scotia Sea at the Antarctic Peninsula and the northern reaches of the Weddell Sea (Area 48). Adult krill form large patches and swarms, and the fishery targets these swarms using midwater trawls. Since the 1990s, most of the fishing activity has occurred in the Atlantic sector of the Southern Ocean; in the past 10 years, the fishery has become concentrated in the region of the Bransfield Strait off the Antarctic Peninsula (Subarea 48.1), to the northwest of Coronation Island (Subarea 48.2), and to the north of South Georgia (Subarea 48.3) (CCAMLR 2015a). Small catches have also been reported from CCAMLR Areas 58 and 88 (Figure 1). Historically, within Area 48, Japan and South Korea have concentrated fishing effort in Subarea 48.1 (Figure 2), and Norway has distributed effort across all the Subareas (48.1–48.3; Figure 2). But fishing effort is highly variable between years and distribution of effort may change significantly in the future (Hill 2013a).

Figure 1: Catches by CCAMLR management area (left) and catches in Subareas 48.1–48.3 (right), where most catches occur (Data from CCAMLR (https://www.ccamlr.org/en/fisheries/krill-fisheries)).
The current estimate of total Antarctic krill biomass in the Southern Ocean is \(\approx 215\) million metric tons (MT) (Hill 2013a). In CCAMLR Subareas 48.1–48.3, where the majority of krill catches occur and where this report is focused, the biomass was estimated to be \(\approx 60\) million MT in 2000. The Antarctic fishery is the largest krill fishery in the world; in 2015, the fishery caught 225,466 MT (CCAMLR 2015a). In comparison, annual catches of *Euphausia pacifica* in Japan are 60,000 to 70,000 MT, and another small fishery for *E. pacifica* occurs in the strait of Georgia in British Columbia, where the annual catch limit is 500 MT.

Two companies from Norway (AkerBioMarine and Rimfrost) are MSC certified. In 2015, these companies caught \(\approx 60\%\) of the total reported krill catch in the Southern Ocean (117,000 MT by AkerBioMarine, 18,918 MT by Rimfrost). This report covers all catches in the Southern Ocean, including those from MSC-certified companies.

**Production statistics**

Exploration of the krill fishery began in the 1960s. Catches of krill peaked in 1981–1982 at 528,201 MT; the total catch of krill reported in 2015 in Subareas 48.1–48.3 was 225,466 MT, about 50\% of which was taken from Subarea 48.1 (CCAMLR 2015a). Recent developments (after the year 2000) in the krill fishery are reviewed in Nicol et al. (2012). China, South Korea, and Norway currently have the highest fishing effort (in fishing days) (Figure 3). The countries responsible for the largest krill catches and their 2014 landings are: Norway (165,899 MT), South Korea (55,414 MT), China (54,303 MT), Chile (9,601 MT), and Ukraine (8,928 MT) (Figure 4 (CCAMLR 2016)). The future of the fishery is uncertain; catches have remained quite low relative to the catch limit set by CCAMLR, but changes in harvesting technology, new products, and new vessels and countries entering the fishery are likely in the next decade (Nicol et al. 2012).
Figure 2: Effort (in fishing days) for China, Japan, South Korea, and Norway by Subarea (48.1–48.3). There has been little effort in the other areas since 1990.
Figure 3: Effort (in fishing days) for all countries in the Antarctic krill fishery that fished more than 100 cumulative hours between 2010–2014 (Data from CCAMLR (accessed March 2016)).
Figure 4: Total capture production of *E. superba* since 1950 (Data from FAO, accessed March 2016).

**Importance to the US/North American market**

Globally, krill products are sold either as boiled and frozen krill for human consumption, krill oil for human consumption, fresh frozen krill for animal feed, or krill meal. The main krill product (by volume) imported to the United States is whole bodies for animal feed, and the main exporters to the United States are South Korea, Japan, China, and Canada (Figure 5). Krill meal is used in the U.S. for pet food, and krill oil is sold as a dietary supplement. The majority of the catch is currently captured by Norway and South Korea, although Chinese vessels caught nearly as much as Korean vessels in 2014 (CCAMLR 2016).
Figure 5: Total imports of krill to the U.S. since 2001. The top panel includes krill imported for human consumption and the bottom panel shows krill imported solely for animal feed. Imports for 2016 are year-to-date (as of March 2016) (Data are from NOAA NMFS).

Common and market names
Krill is the only FDA-accepted name for *E. superba*.

Primary product forms
Krill is sold as whole bodies for animal feed. It is also reduced to krill oil or meal—the oil is sold as a nutritional supplement for humans and meal is often sold as an additive to animal feed. The majority of Antarctic krill catch is processed onboard the trawlers that capture it.
Analysis

This section assesses the sustainability of the fishery(s) relative to the Seafood Watch Criteria for Fisheries, available at http://www.seafoodwatch.org.

Criterion 1: Impact on the Species Under Assessment

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. When abundance is unknown, abundance is scored based on the species’ inherent vulnerability, which is calculated using a Productivity-Susceptibility Analysis. The final Criterion 1 score is determined by taking the geometric mean of the abundance and fishing mortality scores. The Criterion 1 rating is determined as follows:

• Score >3.2=Green or Low Concern
• Score >2.2 and <=3.2=Yellow or Moderate Concern
• Score <=2.2=Red or High Concern

Criterion 1 Summary

<table>
<thead>
<tr>
<th>Stock</th>
<th>Fishery</th>
<th>Abundance Category (Score)</th>
<th>Fishing Mortality Category (Score)</th>
<th>Criterion 1 Rating Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antarctic krill (Euphausia superba)</td>
<td>Krill - Southern Ocean, midwater trawl</td>
<td>Moderate (2.33)</td>
<td>Moderate (3)</td>
<td>Yellow 2.64</td>
</tr>
</tbody>
</table>

Criterion 1 Assessment

*Antarctic krill, Southern Ocean, midwater trawl*

Factor 1.1 Abundance – Moderate Concern

Scoring Guidelines

• 5 (Very Low Concern)—Strong evidence exists that the population is above an appropriate target abundance level (given the species’ ecological role), or near virgin biomass.
• 3.67 (Low Concern)—Population may be below target abundance level, but is at least 75% of the target level, OR data-limited assessments suggest population is healthy and species is not highly vulnerable.

• 2.33 (Moderate Concern) — Population is not overfished but may be below 75% of the target abundance level, OR abundance is unknown and the species is not highly vulnerable.

• 1 (High Concern)—Population is considered overfished/depleted, a species of concern, threatened or endangered, OR abundance is unknown and species is highly vulnerable.

Key relevant information:

The long-term average krill biomass based on scientific net surveys conducted between 1926 and 2004 was 379 million MT (Atkinson et al. 2009). The most recent survey of krill biomass in Subareas 48.1 to 48.4 occurred in 2000, and the Scientific Committee agreed in 2010 that the best biomass estimate from the CCAMLR-2000 Survey was 60.3 million MT (in Area 48; survey CV of 12.8%). Using the approach of Atkinson et al. (2009), this suggests that the total biomass in the Southern Ocean at around January–February 2000 was ≈215 Million MT (Hill 2013a).

Information about krill biomass is poor because the survey used to estimate biomass is more than 15 years old. This places krill in a “low” information tier according to the Lenfest Forage Fish Task Force (Pikitch, E. et al. 2012), which means that a precautionary approach is advised. The catch limit for Antarctic krill is designed to prevent the depletion of krill below 75% of its unfished spawning biomass (to account for predator requirements) and is considered highly precautionary. CCAMLR bases its estimates of standing stock biomass on the CCAMLR-2000 survey, and these biomass estimates have been revised as analytic methods for acoustic data improve. Krill biomass and density can change significantly in a short amount of time (4- to 5-year periods [Fielding et al. 2012]); krill is patchily distributed within its range (Murphy et al. 1998); and it is subject to a high amount of biomass variation over time (Kawaguchi and Nicol 2015). This variability is expected to increase with changes in climate; a review by Flores et al. (2012) found that krill recruitment is both highly variable and sensitive to climate change. The high spatial and temporal variability make it difficult to determine the spawning stock biomass in a given location and year. Because data used to estimate total biomass are over 15 years old, and spatial and temporal variation increase the degree of uncertainty in the biomass estimate, this factor is scored as “moderate” concern.

Detailed rationale (optional)

The stock assessment for Antarctic krill, the "Generalized Yield Model" or GLM (de la Mare 1996) (Constable and de la Mare 2011), is an age-structured population projection model. Biomass is estimated from hydroacoustic surveys, the most recent of which occurred in 2000. The current catch limits for Subareas 48.1–48.4 are set using data from a four-ship acoustic survey carried out in 2000 (Trathan et al. 2001). As improved methods for analyzing acoustic data have become available, these methods have been used to analyze the 2000 survey data. In
2007, the 2000 acoustic data was reanalyzed and updated to 38.29 million MT. In 2010, the Scientific Committee agreed that the best estimate of krill biomass in Subareas 48.1–48.4 from the 2000 acoustic survey was 60.3 million MT, with a survey CV of 12.8%.

Other regional acoustic surveys of Antarctic krill biomass lead by national programs have taken place around South Georgia, South Orkneys, and the Antarctic Peninsula since the last comprehensive survey (e.g., (Siegel 2005) (Warren and Demer 2010) (Siegel et al. 2013)). The UK and Norway have been taking acoustic krill surveys using fishing vessels since 2011 (SC-CAMLR 2015 Annex 6 Paragraphs 2.233-2.234). But the CCAMLR survey from 2000 is still the most recent synoptic dataset.

A recent report by the International Union for the Conservation of Nature (IUCN) on krill used the trend in krill biomass estimates over the last 15 years (three krill generation times) to evaluate the decline in krill biomass, and it found considerable inter- and intra-annual fluctuations in density (according to acoustic surveys and net surveys) at a single location. But between the two time series that were used (one from South Georgia (Fielding et al. 2014) and one from Elephant Island (Cossio et al. 2011)), they did not find a significant trend in the data (Kawaguchi and Nicol 2015).

**Productivity-Susceptibility Analysis (if Applicable):**

N/A

**Factor 1.2 Fishing mortality – Moderate Concern**

*Scoring Guidelines*

- **5 (Low Concern)** — Probable (>50%) that fishing mortality from all sources is at or below a sustainable level, given the species ecological role, OR fishery does not target species and fishing mortality is low enough to not adversely affect its population.

- **3 (Moderate Concern)** — Fishing mortality is fluctuating around sustainable levels, OR fishing mortality relative to a sustainable level is uncertain.

- **1 (High Concern)** — Probable that fishing mortality from all source is above a sustainable level.

**Key relevant information:**

There are no estimates of fishing mortality for Antarctic krill and, because the biomass estimate used to calculate the catch limit is more than 15 years old, any calculation of fishing mortality would not be current. Based on the size of catch limits relative to the estimated size of the spawning stock for krill, fishing alone is not expected to have a large impact on abundance for Antarctic krill. This would normally result in a score of high concern according to Seafood Watch criteria, but the score has been mitigated because there is a precautionary management strategy in place. Therefore, krill is ranked as “moderate” concern for fishing mortality.
According to catches reported to CCAMLR, total catches are currently lower than historical catches (Figure 4). The catch is currently below the trigger level (620,000 MT) in Subareas 48.1–48.4, which is the level beyond which the fishery cannot proceed without an agreed-upon mechanism for spatially distributing further catches, to prevent local depletion. As of 2015, the catch limit was 155,000 MT in Subarea 48.1, 279,000 MT in each Subarea 48.2 and 48.3, and 93,000 MT in Subarea 48.4. Although the catch limits in each subarea add up to more than the trigger level, catch limits for all subareas remain at 620,000 t. In 2010, CCAMLR agreed to the current precautionary catch limit of 5.61 million MT per season in Subareas 48.1–48.4 combined. This was based on a revised analysis of the biomass survey data from 2000, which was $B_0 = 60.3$ million MT (survey CV = 12.8%), and corresponded to a fishery exploitation rate of 0.093, using the Generalized Yield Model described below. In 2014, the total catch from Subareas 48.1–48.3 was 293,815 MT, which was just 5% of the catch limit.

There is some concern that there is significant additional mortality inflicted on krill by the fishing gear (escape mortality), in addition to fishing mortality (SC-CAMLR 2010). Some reports suggest that there is significant mortality to krill that do not end up in the cod end of the trawl, such that the true fishing mortality is higher than what is reported based on catches only (Nicol et al. 2012). There are currently no estimates of this escape mortality available, but Norway and Russia are evaluating escape mortality (Krafft et al. 2015). The CCAMLR Scientific Committee has also expressed concern that the methods used to calculate the “green weight” (the actual amount of krill caught, as opposed to the weight calculated from products) of landed krill vary significantly between vessels and countries, and this introduces uncertainty in the estimates of total take by the fishery (Nicol et al. 2012). CCAMLR has urged ships to report green weight separately from the total weight processed (2014), but there are still vessel-specific differences in green weight estimation methods and thus uncertainty in the total catches.

The current catch limit for krill is precautionary, and as of 2011, the precautionary catch limit for the entire Southern Ocean (8.6 million tons per year) was over 40 times the current annual catch (225,466 MT in Subareas 48.1–48.3 in 2015). Krill has been called one of the largest underexploited marine stocks (Nicol et al. 2012), and the conservative catch limits are intended as a buffer for the stock. Although it is unlikely that the fishery in its current state has a strong impact on the mortality of the stock, a precise estimate of fishing mortality would require more reliable and up-to-date survey data. Additionally, the magnitude of recruitment variability in the population may not sustain krill harvests above the trigger limit in Area 48 (Kinzey et al. 2013). Although the current harvest is highly precautionary, fishing mortality is not known precisely and estimates would improve with more current krill biomass data. Because of the high interannual variability in krill biomass, fishing mortality is expected to be currently low but highly variable.
Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated under Criterion 2. Seafood Watch® defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghost fishing. Species are evaluated using the same guidelines as in Criterion 1. When information on other species caught in the fishery is unavailable, the fishery’s potential impacts on other species is scored according to the Unknown Bycatch Matrices, which are based on a synthesis of peer-reviewed literature and expert opinion on the bycatch impacts of each gear type. The fishery is also scored for the amount of non-retained catch (discards) and bait use relative to the retained catch. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard/bait score. The Criterion 2 rating is determined as follows:

- Score >3.2=Green or Low Concern
- Score >2.2 and <=3.2=Yellow or Moderate Concern
- Score <=2.2=Red or High Concern

Criterion 2 Summary

The Antarctic krill fishery is generally acknowledged as a low-bycatch fishery. The aggregating behavior of krill leads to large, single-species swarms, and the fishery tends to target the center of the swarms because they contain the most high-value catches. One exception is continuous trawling vessels, which target the edges of swarms to avoid filling continuous trawls faster than krill can be processed onboard. Non-target catches in the Antarctic krill fishery are difficult to quantify despite using standard recording forms in the SISO program, because observer recording practices still vary among vessels and countries, and gear designs vary among vessels.

When juveniles and adults, krill display strong schooling behavior, forming large dense aggregations (from several hundred meters to several kilometers horizontally and tens of meters vertically (Watkins 2000)). Because krill are processed in bulk onboard, and krill catches with low bycatch are higher in value, there is a financial incentive for operators to target centers of schools. The fishery usually targets the centers of these schools to maximize the density and quality of krill catch and minimize bycatch of predators and other pelagic species (Kawaguchi and Nicol 2007) (pers. comm., K. Reid 2016).

Coarse information on bycatch is available from CCAMLR; the most recent bycatch report (Doc. # WG-EMM-14/31 Rev. 1) contains data from 9,303 hauls collected on 60 cruises from 2010 to 2014. The report found that the frequency of occurrence of fish in krill trawls varied from 0.1 to
0.98, but this number is likely to be revised; scientists believe that the highest frequencies were recorded on vessels where observers did not record trawls with zero occurrences (thus inflating the proportion of trawls containing fish (pers. comm., K. Reid 2016). CCAMLR found 14 main taxa for which the frequency of occurrence was > 1% in a single subarea; 7 of those were icefish (Channichthids), with a modal size of < 10 cm. The report extrapolated the mass of fish bycatch from the survey data and estimated that a 200,000-MT krill catch might be expected to contain ≈40 t of *C. gunnari* and ≈38 t of *L. larseni*, “with large confidence intervals around those estimates” (Doc. # WG-EMM-14/31 Rev. 1 summary, CCAMLR 2015a). Proportions of total catch for each species are not yet available from this report; only presence/absence data are available. There are several Antarctic fish species caught in the krill fishery that are not targeted or surveyed, so krill tows are some of the only sources of data about their abundance.

Although there is systematic coverage of the fishery by the scientific observer program, individual observer practices vary between countries and vessels. The CCAMLR Scientific Committee decided to review the most recent bycatch report (Doc. # WG-EMM-14/31 Rev. 1) before releasing catch composition data to the public. Observers record warp strikes for seabirds and collect acoustic data on krill biomass and distribution. From each sampled tow, observers separate 25-kg subsamples and collect data on krill size distribution and species identification for adult and juvenile fishes (pers. comm., K. Reid 2016). Larval fish are not always identified to the genus or species; the level to which IDs are resolved can vary by observer and by the country to which that vessel belongs (pers. comm., K. Reid 2016). Different vessels consistently fishing in the same location can have different reports of bycatch amount and composition, so raw bycatch rates or composition are not easily comparable between countries. CCAMLR is planning to release an updated report of catch composition later this year (2016).

Non-target species do not make up more than 5% of the total catch by weight on krill-targeting vessels. On average across all tows, non-target species often make up < 1% of the total catch by mass (pers. comm., K. Reid 2016). Therefore, guidelines based on percentage mass of catch data may be misleading. The main bycatch species for Antarctic krill were determined from a combination of a literature survey (Everson et al. 1992) (Watters 1996), a review of the bycatch species mentioned in the most recent fishery status report (CCAMLR 2015a), and expert input. Species were designated as main species in the krill fishery if they were caught on krill-targeting vessels and either a) were of unknown stock status or had unknown impacts by the krill fishery on population size, or b) were recorded as frequent bycatch in more than one source (e.g., literature and recent status reports).

Seabird mortalities are rare in the krill fishery. There was one incidental seabird capture in 2014 of one cape petrel (dead) and one gentoo penguin (released alive). Warp strikes\(^2\) are also rare;

\(^2\) **Warp strikes** occur when the wings of birds collide with trawl warps or cables. From BirdLife International: “If the warp hits the outstretched wing of a bird, the wing wraps around the cable and the drag created by the forward motion of the vessel and/or rough seas pulls the bird underwater, where it drowns. This is a cryptic form of
only one (non-fatal) warp strike was observed in 2014 (CCAMLR 2015a). Several boats with scientific observers are noted as having streamers or other devices for avoiding seabird bycatch, but not all vessels are equipped with them. Bird bycatch mitigation devices are not required because seabird bycatch is considered negligible. Warp strikes are rare, potentially because of the slow trawling speed.

The lowest scoring main species for Antarctic krill are Antarctic toothfish (*Dissostichus mawsoni*), blackfin icefish (*Chaenocephalus aceratus*), Antarctic jonasfish (*Notolepis coatsi*), spiny icefish (*Chaenodraco wilsoni*), painted notie (*Nototheniops larseni*), and larval fish. Aside from larval fish, these fish are krill predators that are occasionally recorded in tows. Their poor scoring is based mainly on the lack of information about the status of these species. In fact, for some of these species, observer data from krill-targeting vessels provide the only available population information. Because observer data are highly variable and observers don’t always report all the fish that are caught, these species are scored as conservatively as possible, using Productivity-Susceptibility analysis (Seafood Watch Criteria, 2016).

<table>
<thead>
<tr>
<th>Stock</th>
<th>Abundance Category (Score)</th>
<th>Fishing Mortality Category (Score)</th>
<th>Subscore</th>
<th>Score (subscore*discard modifier)</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antarctic toothfish</td>
<td>Moderate (2.33)</td>
<td>Moderate (3)</td>
<td>2.64</td>
<td>2.64</td>
<td>Yellow</td>
</tr>
<tr>
<td>(<em>Dissostichus mawsoni</em>)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blackfin icefish</td>
<td>Moderate (2.33)</td>
<td>Moderate (3)</td>
<td>2.64</td>
<td>2.64</td>
<td>Yellow</td>
</tr>
<tr>
<td>(<em>Chaenocephalus aceratus</em>)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antarctic jonasfish</td>
<td>Moderate (2.33)</td>
<td>Moderate (3)</td>
<td>2.64</td>
<td>2.64</td>
<td>Yellow</td>
</tr>
<tr>
<td>(<em>Notolepis coatsi</em>)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spiny icefish</td>
<td>Moderate (2.33)</td>
<td>Moderate (3)</td>
<td>2.64</td>
<td>2.64</td>
<td>Yellow</td>
</tr>
<tr>
<td>(<em>Chaenodraco wilsoni</em>)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Painted notie</td>
<td>Moderate (2.33)</td>
<td>Moderate (3)</td>
<td>2.64</td>
<td>2.64</td>
<td>Yellow</td>
</tr>
<tr>
<td>(<em>Nototheniops larseni</em>)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Larval fish (unspecified)</td>
<td>Moderate (2.33)</td>
<td>Moderate (3)</td>
<td>2.64</td>
<td>2.64</td>
<td>Yellow</td>
</tr>
<tr>
<td>Antarctic krill</td>
<td>Moderate (2.33)</td>
<td>Moderate (3)</td>
<td>2.64</td>
<td>2.64</td>
<td>Yellow</td>
</tr>
<tr>
<td>(<em>Euphausia superba</em>)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

mortality with the only obvious evidence coming from dead birds that are returned to the surface during hauling, after becoming snagged on splices.”
<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
<th>Population</th>
<th>Vulnerability</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mackerel icefish ((Champsocephalus gunnari))</td>
<td>Low (3.67)</td>
<td>Moderate (3)</td>
<td>3.32</td>
<td>Green</td>
</tr>
<tr>
<td>Antarctic fur seal ((Arctocephalus gazella))</td>
<td>Moderate (2.33)</td>
<td>Low (5)</td>
<td>3.41</td>
<td>Green</td>
</tr>
<tr>
<td>Patagonian toothfish ((Dissostichus eleginoides))</td>
<td>Low (3.67)</td>
<td>Low (5)</td>
<td>4.28</td>
<td>Green</td>
</tr>
<tr>
<td>Myctophids (\text{unspecified})</td>
<td>Very low (5)</td>
<td>Low (5)</td>
<td>5.00</td>
<td>Green</td>
</tr>
</tbody>
</table>

**Criterion 2 Assessment**

*Antarctic toothfish (Dissostichus mawsoni) - Southern Ocean, midwater trawl*

**Factor 2.1 Abundance – Moderate Concern**

**Scoring Guidelines (same as Factor 1.1 above)**

**Key relevant information:**
There is currently little information about the abundance in *D. mawsoni* in the areas where the krill fishery occurs, and the Stock Assessment Working Group has recommended that much more data be collected in order to assess the abundance of *D. mawsoni* (CCAMLR 2015b). There is a small research fishery for *D. mawsoni* in Area 48.2, which overlaps with the location of the krill fishery. A longline survey by Ukraine in 2014/2015 revealed that *D. mawsoni* is present in Subarea 48.2, which confirms that its habitat overlaps with the krill fishery (CCAMLR 2015b). Catches of *D. mawsoni* in Area 48.2 were 31 MT in 2015; 157 were tagged and released. Productivity-Susceptibility Analysis (PSA) for *D. mawsoni* was used to determine a Vulnerability score of Medium (V = 3.159; see Detailed Rationale for full explanation). Because there is no stock assessment for *D. mawsoni* in Subareas 48.1–48.3, *D. mawsoni* abundance is considered “moderate” concern based on its vulnerability score.

**Detailed rationale (optional):**

**Productivity-Susceptibility Analysis**

**Scoring Guidelines**

1.) Productivity score \(P\) = average of the productivity attribute scores \(p1, p2, p3, p4 \text{ (finfish only)}, p5 \text{ (finfish only)}, p6, p7, \text{ and } p8 \text{ (invertebrates only)}\)
2.) Susceptibility score \( (S) \) = product of the susceptibility attribute scores \( (s_1, s_2, s_3, s_4) \), rescaled as follows: \( S = \left[ (s_1 * s_2 * s_3 * s_4) - 1/40 \right] + 1. \)

3.) Vulnerability score \( (V) \) = the Euclidean distance of \( P \) and \( S \) using the following formula: \( V = \sqrt{(P_2 + S^2)} \)

**Vulnerability Score Range**
- \(< 2.64 = \text{Low vulnerability}\)
- \(\geq 2.64 \text{ and } \leq 3.18 = \text{Medium vulnerability}\)
- \(3.18 = \text{High vulnerability}\)

For details on the PSA method and scoring, please see the Seafood Watch Criteria

The PSA score for Antarctic toothfish is \( V = 3.159 \). For this reason, it is considered to have medium vulnerability and thus is scored moderate concern.

<table>
<thead>
<tr>
<th>Productivity Attribute</th>
<th>Relevant Information</th>
<th>Score (1 = low risk, 2 = medium risk, 3 = high risk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age at maturity</td>
<td>16 (Parker and Grimes 2010)</td>
<td>3</td>
</tr>
<tr>
<td>Average maximum age</td>
<td>39 (Brooks et al. 2011)</td>
<td>3</td>
</tr>
<tr>
<td>Fecundity</td>
<td>0.03 to 0.61 million eggs per year (Piyanova et al. 2008)</td>
<td>1</td>
</tr>
<tr>
<td>Average maximum size (fish only)</td>
<td>200 cm TL male/unsexed (Eastman and DeVries 2000)</td>
<td>2</td>
</tr>
<tr>
<td>Average size at maturity (fish only)</td>
<td>90–100 cm (Eastman and DeVries 2000)</td>
<td>2</td>
</tr>
<tr>
<td>Reproductive strategy</td>
<td>Broadcast spawner (Hanchet et al. 2008)</td>
<td>1</td>
</tr>
<tr>
<td>Trophic level</td>
<td>&gt; 3.25 (Hanchet et al. 2015)</td>
<td>3</td>
</tr>
<tr>
<td>Density dependence (invertebrates only)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Susceptibility Attribute</th>
<th>Relevant Information</th>
<th>Score (1 = low risk, 2 = medium risk, 3 = high risk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areal overlap (Considers all fisheries)</td>
<td>No information available (use default score)</td>
<td>3</td>
</tr>
<tr>
<td>Vertical overlap (Considers all fisheries)</td>
<td>No information available (use default score)</td>
<td>3</td>
</tr>
<tr>
<td>Selectivity of fishery (Specific to fishery under assessment)</td>
<td>No information available (use default score)</td>
<td>2</td>
</tr>
<tr>
<td>Post-capture mortality (Specific to fishery under assessment)</td>
<td>No information available (use default score)</td>
<td>3</td>
</tr>
</tbody>
</table>

**Factor 2.2 Fishing Mortality – High Concern**

*Scoring Guidelines (same as Factor 1.2 above)*

**Key relevant information:**
*D. mawsoni* is fished in other areas of the Southern Ocean (e.g., Subarea 48.4, where there is a fishery and an assessment); however, there is only a limited scientific fishery in Subareas 48.1–48.3. Because there is no information available about fishing mortality for *D. mawsoni*, it is ranked “moderate” concern.

**Detailed rationale (optional):**
Although it is targeted in a fishery in the Ross Sea, *D. mawsoni* is not fished heavily in the areas where the krill fishery occurs. There are *D. mawsoni* populations in krill fishing Subareas 48.1, 48.2, and 48.4, and small fisheries in Subareas 48.2 and 48.4 (CCAMLR 2016). Total catches in both Subareas 48.2 and 48.4 have never surpassed 60 MT, although IUU fishing has been a problem for *D. mawsoni* in other areas and may be a concern here.

*Blackfin icefish (Chaenocephalus aceratus) – Southern Ocean, midwater trawl*

**Factor 2.1 Abundance – Moderate Concern**

*Scoring Guidelines (same as Factor 1.1 above)*

**Key relevant information:**
There are several stocks of *C. aceratus* throughout the Southern Ocean. Although there is no official stock assessment for blackfin icefish in Subareas 48.1–48.3, recent reconstruction of the abundance of *C. aceratus* over time suggests that abundance has declined from 18,000 MT to 6,000 MT since the start of the fishery in 1977 (Nicol 1990). According to Kock (1992), the estimated stock size of *C. aceratus* in South Georgia in 1990 was 15,000 MT. Because of the unknown current status of the stock and the declining trend in biomass, *C. aceratus* is ranked using the Unknown Bycatch Matrix (Seafood Watch 2015) and considered “moderate” concern.
**Detailed rationale (optional):**

**Factor 2.2 Fishing Mortality – Moderate Concern**

*Scoring Guidelines (same as Factor 1.2 above)*

**Key relevant information:** The amount of *C. aceratus* mortality that is caused by the krill fishery is unknown. Everson (1992) documented *C. aceratus* in krill catches in 1981–87, and they currently appear in < 10% of krill catches (pers. comm., K. Reid 2016). Because of the absence of information about current *C. aceratus* fishing mortality in the krill fishery and its overall fishing mortality across fisheries, fishing mortality is considered unknown and a “moderate” concern.

**Detailed rationale (optional):**

*Antarctic jonasfish (Notolepis coatsi) – Southern Ocean, midwater trawl*

**Factor 2.1 Abundance – Moderate Concern**

**Key relevant information:**
There is currently no population assessment for Antarctic jonasfish. Its FishBase vulnerability score is 41 out of 100 (moderate vulnerability). Because there are no abundance or biomass surveys for *N. coatsi*, it was evaluated using Seafood Watch’s Productivity-Susceptibility Analysis of vulnerability (PSA; Seafood Watch 2016; Appendix 2). Its PSA score of 2.76 (P = 1.5, S = 2.32) equals medium vulnerability and is rated “moderate” concern.

**Productivity-Susceptibility Analysis**

*Scoring Guidelines*

1.) Productivity score (P) = average of the productivity attribute scores (p1, p2, p3, p4 (finfish only), p5 (finfish only), p6, p7, and p8 (invertebrates only))

2.) Susceptibility score (S) = product of the susceptibility attribute scores (s1, s2, s3, s4), rescaled as follows: $SS = [(s1 * s2 * s3 * s4) - 1/40] + 1$.

3.) Vulnerability score (V) = the Euclidean distance of P and S using the following formula: $V = \sqrt{P^2 + S^2}$

**Vulnerability Score Range**

- < 2.64 = Low vulnerability
- ≥ 2.64 and ≤ 3.18 = Medium vulnerability
- 3.18 = High vulnerability

*For details on the PSA method and scoring, please see the Seafood Watch Criteria*

The PSA score for Antarctic jonasfish is $V = 2.76$. For this reason, it is considered medium vulnerability and thus moderate Concern.
<table>
<thead>
<tr>
<th>Productivity Attribute</th>
<th>Relevant Information</th>
<th>Score (1 = low risk, 2 = medium risk, 3 = high risk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age at maturity</td>
<td>Unknown</td>
<td>N/A</td>
</tr>
<tr>
<td>Average maximum age</td>
<td>Unknown</td>
<td>N/A</td>
</tr>
<tr>
<td>Fecundity</td>
<td>Unknown</td>
<td>N/A</td>
</tr>
<tr>
<td>Average maximum size (fish only)</td>
<td>38 cm (male) (Post 1990)</td>
<td>1</td>
</tr>
<tr>
<td>Average size at maturity (fish only)</td>
<td>Unknown</td>
<td>N/A</td>
</tr>
<tr>
<td>Reproductive strategy</td>
<td>Unknown</td>
<td>N/A</td>
</tr>
<tr>
<td>Trophic level</td>
<td>3 (FishBase)³</td>
<td>2</td>
</tr>
<tr>
<td>Density dependence (invertebrates only)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Susceptibility Attribute</th>
<th>Relevant Information</th>
<th>Score (1 = low risk, 2 = medium risk, 3 = high risk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areal overlap</td>
<td>No information available (use default score)</td>
<td>3</td>
</tr>
<tr>
<td>Vertical overlap</td>
<td>No information available (use default score)</td>
<td>3</td>
</tr>
<tr>
<td>Selectivity of fishery</td>
<td>No information available (use default score)</td>
<td>2</td>
</tr>
<tr>
<td>Post-capture mortality</td>
<td>No information available (use default score)</td>
<td>3</td>
</tr>
</tbody>
</table>

³ This is a theoretical estimate provided by FishBase.
Factor 2.2 Fishing Mortality – Moderate Concern

Scoring Guidelines (same as Factor 1.2 above)

Key relevant information:
There are no catch composition data currently available that indicate the proportion of *N. coatsi* in the krill-directed catch. If no data on *N. coatsi* were available at all, it would be scored as high concern because it is a pelagic fish in a midwater trawl fishery. There is anecdotal evidence that Antarctic jonasfish is caught in 5%–10% of krill tows (pers. comm., K. Reid 2016). Because the impact of the krill fishery on this species is unknown, it is scored as “moderate” concern.

**Spiny icefish (Chaenodraco wilsoni) – Southern Ocean, midwater trawl**

Factor 2.1 Abundance – Moderate Concern

Key relevant information:
*C. wilsoni* has been targeted in the Antarctic in the past, but it is not a regularly assessed stock. Icefishes as a group are slow to mature (5–8 years old at maturity) and grow rapidly (6–10 cm a year (LaMesa et al. 2009)); however, their present abundance is unknown. *C. wilsoni* has not been a target of the fishery since CCAMLR was established, so historical abundance data are unavailable. Because of the lack of stock status or trend information, *C. wilsoni* are considered “moderate” concern.

Factor 2.2 Fishing Mortality – Moderate Concern

Scoring Guidelines (same as Factor 1.2 above)

Key relevant information: *C. wilsoni* appears in ≈5%–10% of krill tows in groups of one or two fish per tow (pers. comm., K. Reid 2016). The proportion of *C. wilsoni* in the total catch of the krill fishery is mostly unknown, but the krill fishery likely catches them while they are foraging for krill or other pelagic prey. Because of the absence of information about *C. wilsoni* fishing mortality in the krill fishery and its overall fishing mortality across fisheries, fishing mortality is considered unknown and a “moderate” Concern.
Painted notie (Nototheniops larseni) – Southern Ocean, midwater trawl

Factor 2.1 Abundance – Moderate Concern

Key relevant information:
The inherent vulnerability for *N. larseni* is 34 of 100, which is considered to be low to moderate inherent vulnerability. But the stock status for *L. larseni* is unknown, so it is considered “moderate” Concern.

Factor 2.2 Fishing Mortality – Moderate Concern

Scoring Guidelines (same as Factor 1.2 above)

Detailed rationale (optional): Painted notie is among the fish species most frequently caught by the Antarctic krill fishery (pers. comm., K. Reid). There is anecdotal evidence that *N. larseni* feed around the edges of krill swarms, so that ships targeting the centers of the swarms would generally avoid catching large numbers of painted notie. Because of the absence of information about *N. larseni* fishing mortality in the krill fishery and its overall fishing mortality across fisheries, fishing mortality is considered unknown and a “moderate” concern.

Larval fish (unspecified) – Southern Ocean, midwater trawl

Factor 2.1 Abundance – Moderate Concern

Scoring Guidelines (same as Factor 1.1 above)

Key relevant information: The abundance of larval fish in the Southern Ocean is unknown but is assumed to be proportional to the abundance of adult fish of the same species. There are assessments available for *C. gunnari*, but abundance estimates are not available for lanternfish (Family Myctophidae) and rockcod (*Notothenia rossii*), two other groups whose larvae are commonly caught in krill trawls. Although *C. gunnari* is known to be at or above its target biomass level, recruitment and recruitment variation for all larval fish species is largely unknown. There are also significant changes in larval abundance with seasonal changes and shifts in ice cover (Loeb et al. 1993). Because larval fish are common in krill tows and biomass/abundance estimates are not available, larval fish are considered “moderate” concern.

Detailed rationale (optional):

Factor 2.2 Fishing Mortality – Moderate Concern

Scoring Guidelines (same as Factor 1.2 above)

Key relevant information: Larval fish are often documented in catches in the krill fishery and have been flagged by CCAMLR’s Scientific Committee as an area of concern. Mackerel icefish
larvae (*Champsocephalus gunnari*) and marbled rockcod larvae (*Notothenia rossii*), as well as lanternfish (family Myctophidae) larvae, are common in krill trawls (Bibik and Zhuk 2008), although larvae are not always identified to the species level. Fish larvae make up less than 5% of the catch on Norwegian vessels (MRAG 2009), which were certified by MSC in 2015, but the composition of the larval catch and the variation among vessels, subareas, and years is still highly uncertain. Because of the unknown total impact of the krill fishery on this group, larval fish as a group are considered “moderate” concern.

**Detailed rationale (optional):** Estimates of how much larval fish make up each tow are uncertain, according to CCAMLR. Observer data are often not well resolved enough to determine the species composition of larval fish caught in krill trawls; larval fish are more often identified to the family level. The bycatch of larval fishes has been a concern of the Scientific Committee for some time, and observer sampling for krill and fish larvae is crucial to determining the extent to which bycatch occurs.

**Mackerel icefish (*Champsocephalus gunnari*) - Southern Ocean, midwater trawl**

**Factor 2.1 Abundance – Low Concern**

**Scoring Guidelines (same as Factor 1.1 above)**

**Key relevant information:**
Recent biomass estimates (from acoustic and trawl surveys) from CCAMLR indicate that *C. gunnari* in Subarea 48.3 is at or above its long-term average biomass (as of 2015, biomass was estimated to be 59,081 MT and slightly above the average since 2000, with a one-sided lower 95% confidence interval of 36,530 MT (CCAMLR 2015a) (SC-CAMLR 2015)). A survey by the UK in January 2015 of the South Georgia (Subarea 48.3) and Shag Rocks areas estimated a total of 59,081 MT, which was slightly above the average since 2000. *C. gunnari* in Subarea 58.5.2 is characterized by large fluctuations in biomass (CCAMLR WG-FSA-11/34). But because two data sources indicate that biomass is currently above its long-term mean biomass, *C. gunnari* is scored “low” concern.

**Detailed rationale (optional):**
The stock assessment for *C. gunnari* uses length frequency and biomass density to estimate biomass, and the harvest control rule is set using this length-based approach. The details of the stock assessment for *C. gunnari* are contained in WG-FSA-15/25. Estimates of *C. gunnari* biomass are taken from stratified random bottom trawl surveys, which have been carried out by UK vessels since 1986.

The abundance of *C. gunnari* has been linked to the abundance of krill, which is their main prey. Krill predators such as gentoo penguins and fur seals can also switch to eating *C. gunnari* in years when krill availability is lower. Therefore, there is some concern that an expanded krill fishery would cause higher fishing mortality for *C. gunnari*. 

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**Factor 2.2 Fishing Mortality – Moderate Concern**

*Scoring Guidelines (same as Factor 1.2 above)*

Key relevant information:
The direct impact of the krill fishery on *C. gunnari* population sizes is unknown. But mackerel icefish is a main predator of krill and one of the most common species caught in krill trawls (<30 MT/year across the whole krill fishery (pers. comm., K.Reid)). Moreover, the total catch of *C. gunnari* reported in 2015 was 277 MT, so 30 MT could be a significant proportion of the total fishing mortality for the stock. There are not yet explicit limit reference points for *C. gunnari*, but the length-based model used to calculate catch limits has been demonstrated to give robust precautionary estimates of catch limits (SC-CAMLR 2015). Because of the high uncertainty about the impact of the fishery, *C. gunnari* is conservatively ranked as “moderate” concern.

**Antarctic fur seal (Arctocephalus gazella) – Southern Ocean, midwater trawl**

**Factor 2.1 Abundance – Moderate Concern**

*Scoring Guidelines (same as Factor 1.1 above)*

Key relevant information:
The largest population of fur seals is on the island of South Georgia, which supports about 95% of all Antarctic fur seals, according to the most recent IUCN report (IUCN 2008). In 1999/2000, when the last survey occurred, the total population was estimated between 4.5 and 6.2 million seals, and is believed to have increased by 6%–14% since the 1990/1991 season (IUCN 2008). In 2004, all populations of fur seals are believed to be either increasing or stable (SCAR EGS 2004), but dynamics seem to be driven by different factors (bottom-up vs. top-down) in different locations (Schwarz et al. 2013), so it is possible that larger trends mask local dynamics. Assessments of fur seal population size in Area 48, where the krill fishery occurs, are not currently available. Because of the lack of fur seal abundance information for krill fishing areas but given the general recovery of fur seal populations, fur seal abundance is considered “moderate” concern.

Detailed rationale (optional): Antarctic fur seals in some locations are experiencing gradual declines, but dynamics and the drivers (bottom-up vs. top-down) vary between subpopulations (Schwarz et al. 2013).
Factor 2.2 Fishing Mortality – Low Concern

*Scoring Guidelines (same as Factor 1.2 above)*

**Key relevant information:**
Mortalities of fur seals in the krill fishery have declined over time, but were sometimes substantial before the mandatory deployment of seal exclusion devices. In 2003, 73 Antarctic fur seals were caught by one vessel in the krill fishery (26 were killed and 47 were released alive) (CCAMLR 2015a). In 2004, SISO observers in Area 48 recorded 292 fur seals caught in Subarea 48.3. This number declined to 97 in 2005, and rules that seal exclusion devices had to be attached to each vessel were implemented. Between 2008 and 2014, there were no fur seal mortalities reported, and two were reported in 2015. It is unlikely that these fishing-related mortalities compose a large proportion of the total mortality experienced by fur seals, so fur seal is considered “low” concern for fishing mortality.

**Detailed rationale (optional):**
No Antarctic fur seal catches were reported prior to 2003. In 2003, one vessel captured 73, and 292 fur seals were caught in Subarea 48.3 in 2004. The Scientific Committee then recommended that the Commission require observers on vessels to improve bycatch mitigation efforts (SC-CAMLR-XXIII, Annex 5, paragraph 7.236; CCAMLR 2015a) and released documentation on seal exclusion devices (SEDs) among CCAMLR members. In 2005, 97 fur seal mortalities were recorded in Area 48, but observer coverage was low (only four of nine trawl vessels submitted bycatch reports). In 2006 and 2007, one fur seal was captured each year. In 2008, six more seal mortalities were reported in Subarea 48.3, and in 2008 the Committee amended the general mitigation provisions to require SEDs on all vessels operating in Area 48 (CM 51-01), as well as regulated mesh sizes and cod end sizes to mitigate seal bycatch and mortality. Since these measures were enacted, fur seal bycatch has been very low; no mortalities were reported between 2008 and 2014, although two were reported in 2015.

*Patagonian toothfish (Dissostichus eleginoides) - Southern Ocean, midwater trawl*

Factor 2.1 Abundance – Low Concern

*Scoring Guidelines (same as Factor 1.1 above)*

**Key relevant information:**
Patagonian toothfish has a high inherent vulnerability, and stock status varies by location. Although CCAMLR manages this species in Area 48 where it is most likely to be caught in the krill fishery, biomass trends are not available and population size is currently being assessed through a mark-recapture study. The most recent stock assessment for *D. eleginoides* in Subarea 48.3 was in 2015. In Subarea 48.3, $B_{2015}/B_0$ was estimated to be 0.84. CCAMLR’s reference points are based on pristine or unfished spawning stock biomass ($SSB_0$), and catch limit rules are designed to maintain stocks at $\geq 0.5 SSB_0$. Stochastic projections by CCAMLR
indicate that a constant yield of 2,400 MT will maintain SSB above 50% of $B_0$ over the next 35 years with 50% probability (SC-CAMLR 2014). Because there is a stock assessment, which indicates that biomass is above this reference point, abundance is considered “low” concern.

**Factor 2.2 Fishing Mortality – Low Concern**

*Scoring Guidelines (same as Factor 1.2 above)*

**Key relevant information:**
For all the stocks of Patagonian toothfish evaluated by Seafood Watch in 2014, the fishing mortality rate did not exceed estimated natural mortality (SFW 2014). More recent estimates of fishing mortality are not available. Therefore, Patagonian toothfish is considered “low” concern for fishing mortality.

**Detailed rationale (optional):**
The value of $U$ is calculated as the maximum posterior density (MPD) estimate of annual catch divided by the spawning stock biomass. Where $U$ is less than natural mortality ($M$), stocks are deemed to be able to support that level of exploitation (pers. comm., A. Dunn, cited in SFW Antarctic Toothfish Report).

**Lanternfish (Family Myctophidae) – Southern Ocean, midwater trawl**

**Factor 2.1 Abundance – Very Low Concern**

*Scoring Guidelines (same as Factor 1.1 above)*

**Key relevant information:**
Lanternfish (family Myctophidae) are a dominant mesopelagic fish in the world’s oceans. They are common in the Southern Ocean, where they are considered to be an important alternative prey when krill are in locally low abundance (Saunders et al. 2015). Global biomass estimates for myctophids are around 600 million MT (Gjosaeter and Kawaguchi 1980). Because myctophids are highly abundant, they are considered “very low” concern.
Factor 2.2 Fishing Mortality

Scoring Guidelines (same as Factor 1.2 above)

Key relevant information:
There is no directed fishery for myctophids and, although they may make up > 10% of some krill catches, the krill fishery is unlikely to contribute substantially to their total mortality. Therefore, myctophids are ranked “low” concern for fishing mortality.

Factor 2.3 Modifying Factor: Discards and Bait Use

Scoring Guidelines
The discard rate is the sum of all dead discards (i.e. non-retained catch) plus bait use divided by the total retained catch.

<table>
<thead>
<tr>
<th>Ratio of bait + discards/landings</th>
<th>Factor 2.4 score</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100%</td>
<td>1</td>
</tr>
<tr>
<td>≥100</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Southern Ocean, midwater trawl

Key relevant information:
In the Antarctic krill fishery, estimates for the proportion of bycatch in the total catch range from 4%–12% reported by fishing vessels, but may be up to 56% according to observations reported by the SISO program. This discrepancy is addressed in Criterion 3.2. But none of these estimates is greater than 100%, so retained catches are always greater by weight than discards/bait.
Criterion 3: Management Effectiveness

Five subfactors are evaluated: Management Strategy and Implementation, Bycatch Strategy, Scientific Research/Monitoring, Enforcement of Regulations, and Inclusion of Stakeholders. Each is scored as ‘highly effective’, ‘moderately effective’, ‘ineffective,’ or ‘critical’. The final criterion score is determined as follows:

- **5 (Very Low Concern)** — Meets the standards of ‘highly effective’ for all five subfactors considered.
- **4 (Low Concern)** — Meets the standards of ‘highly effective’ for management strategy and implementation and at least ‘moderately effective’ for all other subfactors.
- **3 (Moderate Concern)** — Meets the standards for at least ‘moderately effective’ for all five subfactors.
- **2 (High Concern)** — At minimum, meets standards for ‘moderately effective’ for Management Strategy and Implementation and Bycatch Strategy, but at least one other subfactor is rated ‘ineffective.’
- **1 (Very High Concern)** — Management Strategy and Implementation and/or Bycatch Management are ‘ineffective.’
- **0 (Critical)** — Management Strategy and Implementation is ‘critical’.

The Criterion 3 rating is determined as follows:

- Score >3.2 = Green or Low Concern
- Score >2.2 and <=3.2 = Yellow or Moderate Concern
- Score <=2.2 = Red or High Concern

Rating is Critical if Management Strategy and Implementation is Critical.

Criterion 3 Summary

<table>
<thead>
<tr>
<th>Fishery</th>
<th>3.1 Mgmt strategy and implement.</th>
<th>3.2 Bycatch Strategy</th>
<th>3.3 Scientific research and monitoring</th>
<th>3.4 Enforcement</th>
<th>3.5 Stakeholder Inclusion</th>
<th>Management Effectiveness Category (Score)</th>
<th>C3 Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krill - Southern Ocean, midwater trawl</td>
<td>Highly Effective</td>
<td>Moderately Effective</td>
<td>Moderately Effective</td>
<td>Moderately Effective</td>
<td>Highly Effective</td>
<td>Moderate (3)</td>
<td>Yellow</td>
</tr>
</tbody>
</table>
Criterion 3 Assessment

Factor 3.1 Management Strategy and Implementation – Highly Effective
Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? Do managers follow scientific advice? To achieve a highly effective rating, there must be appropriately defined management goals, precautionary policies that are based on scientific advice, and evidence that the measures in place have been successful at maintaining/rebuilding species.

Southern Ocean, midwater trawl

Key relevant information:
Antarctic krill is managed by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR). CCAMLR is an international commission with 25 member countries who agree on a set of conservation measures that determine fishery rules and limits. Krill management is carried out in accordance with the CCAMLR Convention. The objective of this convention is the conservation of marine living resources (Article KK.1). For the purpose of this Convention, the term “conservation” includes rational use. Any harvesting and associated activities in the area where the Convention applies are conducted in accordance with principles that include the prevention of a decrease in harvested populations below that which would ensure “stable recruitment” (Article II.3.a) and the maintenance of ecological relationships between fished species and the predators that depend on them. CCAMLR meets annually to determine the catch limits for each fishing season, based on recommendations from the Scientific Committee, although in practice the catch limit for krill in Subareas 48.1 to 48.4 has been fixed at the trigger level since 1991.

To prevent fishing activity from being too concentrated in one subarea, CCAMLR introduced a trigger catch level, above which the fishery cannot proceed unless it has established a mechanism to distribute catches among subareas (CCAMLR 2015a). To allow for the needs of predators that forage at smaller scales, the trigger level is further subdivided: catches in any one season are not allowed to exceed 25% of the trigger level (155,000 MT) in Subarea 48.1, 45% (279,000 MT) each in Subareas 48.2 and 48.3, and 15% (93,000 MT) in Subarea 48.4 (Conservation Measure 51-07). The trigger level as of 2015 is not linked to the assessment of krill biomass, so the trigger level was not changed in 2010 even though the precautionary catch limit changed (CCAMLR 2015a). Whether the subarea scale is the appropriate scale for spatial management is a significant source of uncertainty (e.g., Plaganyi and Butterworth 2012). Because krill recruitment variability is expected to increase with climate change, the Scientific Committee has recommended that the decision rule for maintaining stable recruitment should be studied further (CCAMLR 2015a). Because there are management structures in place to ensure the consistent recruitment of krill, the fishery is ranked “highly effective” for Management Strategy and Implementation.
Detailed rationale (optional):
CCAMLR delegates include scientists, fishers, and NGOs. CCAMLR member countries are active in harvesting or research, contribute financially to CCAMLR, and have voting rights (Constable and De La Mar 2011). As of 2011, there were 25 member countries and 9 contracting parties. CCAMLR receives advice from the Scientific Committee (SC-CAMLR), as well as the Standing Committee on Implementation and Compliance and the Standing Committee on Administration and Finance. SC-CAMLR comprises several working groups, including Fish Stock Assessment, Ecosystem Monitoring and Management, Incidental Mortality Arising from Fishing, and Statistics, Assessments and Modelling (Constable and De La Mar 2011).

CCAMLR sets the yield limit based on an estimate of potential yield. This is calculated using life history parameters from the population, which are fed into a Generalized Yield Model (GYM (de la Mare 1996)) to estimate a range of possible krill population sizes at a range of possible exploitation rates, including a scenario in which there is no fishing, given some stochasticity in recruitment. Exploitation rates are selected by determining two potential exploitation rates: one with which there is a < 10% probability of spawning biomass dropping below 20% of the median pre-exploitation spawning biomass over a 20-year harvesting period, and one that makes it so that the median escapement at the end of a 20-year period is at least 75% of the median pre-exploitation spawning biomass (this 75% escapement rule is made to account for the needs of krill predators). The lower of these two potential harvest rates is then multiplied by the estimated pre-exploitation biomass $B_0$ to determine total allowable catch.

CCAMLR guidelines have also been effective at preventing intense fishing in a single management area. CCAMLR has set Conservation Measure 51-07 in order to spatially distribute catch, which has been successful at regulating localized concentrations of catch in the past 5 years. The trigger point for Subarea 48.1 has been reached a few times during that period, and each time the fishery has been closed. Although it is still debated whether the spatial rules are precautionary enough (a great deal of the fishery in Subarea 48.1 still takes from a single area in Bransfield Strait), CCAMLR has demonstrated the capacity to prevent hyper-localized fishing. Whether spatial management is occurring at a proper scale for predators is still a scientific debate within the Scientific Committee (CCAMLR 2015c) (see Criterion 4 for more information).

CCAMLR responds internally to review. In 2007, CCAMLR undertook a performance review that was carried out by a panel of nine people with expertise in a range of relevant disciplines, including fisheries science and law. The performance review recommendations provided guidance and suggested improvements on several measures, and the review of these recommendations has been incorporated into the annual fishery review process (CCAMLR 2015a).

Factor 3.2 Bycatch Strategy – Moderately Effective
Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and when applicable, to minimize ghost fishing? How successful are these management measures? To achieve a Highly Effective rating, the fishery
must have no or low bycatch, or if there are bycatch or ghost fishing concerns, there must be effective measures in place to minimize impacts.

Southern Ocean, midwater trawl

Key relevant information:

All member countries in CCAMLR are required to have the same bycatch reduction measures. The most recent modifications to the bycatch reduction measures in the Antarctic trawl fisheries were adopted in 2011 (CCAMLR CM 25-03; 2011). They had adopted the following bycatch reduction measures as of 2011: forbidding the use of net monitor cables, minimizing light directed out of the vessel, prohibiting the discarding of waste and offal during shooting or hauling of trawl gear, cleaning nets before shooting to remove items that are attractive to birds, minimizing the time that the trawl net is at the surface of the water (where it can present an entangling hazard to seabirds and mammals), and developing gear configurations that minimize the chances that birds will interact with the net where they are most vulnerable (CCAMLR 2011). Because krill are either frozen or processed en masse aboard vessels and tows, those with the highest proportion of krill are the most valuable, so vessels targeting krill also have an economic incentive to avoid bycatch (pers. comm., K. Reid 2016).

Bycatch is low according to observer data, which would indicate that CCAMLR’s management strategy is effective, but bycatch reporting by vessels is often different from the bycatch recorded by scientific observers, and varies widely between member countries. For this reason, the Antarctic krill fishery is ranked Moderately Effective for bycatch management.

Detailed rationale (optional):

According to the most recent CCAMLR krill fishery report in 2015, the reported frequency of occurrence of bycatch in the commercial fishery has increased over the past three seasons, from 1.34% of hauls in 2013 to 3.76% in 2014 and 12.88% in 2015 (although the 2015 season was incomplete at the time of the report, so 12.88% is likely a lower bound on the true proportion of bycatch). These proportions are much lower than the numbers reported by the Scheme of International Scientific Observation (SISO) program for the same period (39.14%, 48.48%, and 56.46% for 2013, 2014, and 2015, respectively). This discrepancy between observed and reported bycatch rates has been the focus of suggested improvements to observer coverage and vessel reporting requirements.

Factor 3.3 Scientific Research and Monitoring – Moderately Effective

Considerations: How much and what types of data are collected to evaluate the fishery’s impact on the species? Is there adequate monitoring of bycatch? To achieve a Highly Effective rating, regular, robust population assessments must be conducted for target or retained species, and
an adequate bycatch data collection program must be in place to ensure bycatch management goals are met.

Southern Ocean, midwater trawl

Key relevant information:

The managers of the krill fishery often follow the advice of the CCAMLR Scientific Committee. The Scientific Committee meets regularly to discuss sources of uncertainty in the fishery, and data reported at scientific meetings are shared online. The data used to estimate the standing stock biomass of krill come from a comprehensive acoustic survey of biomass in Subareas 48.1–48.4 in 2000, and model estimates from population projections. The survey in 2000 was the most recent, and it is more than 15 years old. In-season catch reporting as well as observer data are used to determine total catch within the season and to estimate impacts on non-target species. Discrepancies between observer data and vessel trip reports have been an issue, and observer coverage is still not always 100% on member vessels (CCAMLR 2015a). Member countries follow their own observer regulations in addition to CCAMLR regulations, but differences between member countries in observer coverage and total catch are not publicly available (pers. comm., K. Reid 2016). Because regulations around scientific research and monitoring are rigorous but there is not strong evidence that they are consistently followed, and observer coverage is expected to improve, the krill fishery is ranked “moderately effective.”

Detailed rationale (optional):

During the 2013 and 2014 seasons, 15 vessels fished for krill. The combined fleet had 80% observer coverage across both years, with minimum coverage of 58% in the summer and 63% in the winter (Krafft et al. 2015). The number of observers on krill-targeting vessels has increased since 2010, after CM 51-06 was adopted in 2009. But the Working Group on Ecosystem Monitoring and Management still recommends a higher observer sampling frequency and more training so that observers can identify fish bycatch to the family level (Krafft et al. 2015).

In addition to the observer program, catch and effort in the krill fishery are reported on a monthly basis. Once the catch in a management area exceeds 80% of the catch limit for that area, then catches are required to be reported every 5 days. When this happens in a single area in one season, the threshold at which catches are reported every 5 days becomes 50% instead of 80% (CCAMLR 2015a). This adaptive approach is intended to increase the ability of CCAMLR to announce spatial closures earlier.
Factor 3.4 Enforcement of Management Regulations – Moderately Effective  

Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

**Southern Ocean, midwater trawl**

Key relevant information:  
CCAMLR member states implement several tools that increase compliance with CCAMLR regulations, including vessel licensing (Conservation Measure 10-02), monitoring of vessel movements (Conservation Measure 10-04), monitoring of vessel transshipments (Conservation Measure 10-09), a vessel monitoring system (VMS; Conservation Measure 10-04), and Catch Documentation (Conservation Measure 10-05). CCAMLR also has a Standing Committee on Implementation and Compliance (SCIC), which meets annually to review compliance systems and conservation measures. CCAMLR keeps track of vessels that violate any of these. The degree of compliance has not yet been quantified and there is no information currently available on the differences in compliance among member countries, but the aforementioned tools make verification and enforcement possible. Because the framework for monitoring compliance exists but compliance data are not available, the krill fishery is considered “moderately effective” for enforcement of management regulations.

Detailed rationale (optional):

Factor 3.5 Stakeholder Inclusion – Highly Effective

Considerations: Are stakeholders involved/included in the decision-making process?  
Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent, if high participation by all stakeholders is encouraged, and if there a mechanism to effectively address user conflicts.

**Southern Ocean, midwater trawl**

Key relevant information:  
Decisions in CCAMLR are taken by consensus by all member countries in CCAMLR (e.g., decisions on catch limits, seasonal or area closures, and other conservation measures with other members). A recent analysis found that the fishing industry, conservation-focused NGOs, and scientists generally agreed that maintenance of ecosystem health was a priority, recognized that setting management objectives was a priority, and thought that the ecosystem was capable of sustaining current catch levels (Cavanagh et al. 2016). Stakeholders and NGOs are present at CCAMLR meetings so that the transparency of the decision-making process is maintained, but they do not have voting privileges. Summary reports of meetings are publicly
available, and mechanisms for addressing stakeholder concerns are built into the regulatory structure of CCAMLR. Because the decision-making process is inclusive of stakeholders and fully transparent, it is rated “highly effective” for stakeholder inclusion.
Criterion 4: Impacts on the Habitat and Ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery’s overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem Based Fisheries Management aims to consider the interconnections among species and all natural and human stressors on the environment. The final score is the geometric mean of the impact of fishing gear on habitat score and the Ecosystem Based Fishery Management score. The Criterion 4 rating is determined as follows:

- Score >3.2=Green or Low Concern
- Score >2.2 and <=3.2=Yellow or Moderate Concern
- Score <=2.2=Red or High Concern

Criterion 4 Summary

<table>
<thead>
<tr>
<th>Fishery</th>
<th>4.1a Gear type and substrate</th>
<th>4.1b Mitigation of gear impacts</th>
<th>4.2 EBFM</th>
<th>Criterion 4 Rating Score</th>
</tr>
</thead>
</table>
| Krill - Southern Ocean, midwater trawl | Score 5                      | Score 0                         | Moderate (3) | Green 3.87

Criterion 4 Assessment

Factor 4.1a Physical Impact of Fishing Gear on the Habitat/Substrate

Scoring Guidelines
- 5 (None)—Fishing gear does not contact the bottom
- 4 (Very Low)—Vertical line gear
- 3 (Low)—Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom longline, trap) and is not fished on sensitive habitats. Or bottom seine on resilient mud/sand habitats. Or midwater trawl that is known to contact bottom occasionally. Or purse seine known to commonly contact the bottom.
- 2 (Moderate)—Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Or gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Or bottom seine except on mud/sand. Or there is known trampling of coral reef habitat.
• 1 (High)—Hydraulic clam dredge. Or dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)
• 0 (Very High)—Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl)

Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.

Southern Ocean, midwater trawl

Key relevant information:

The midwater trawls used to catch krill do not have contact with the seafloor, so they have a score of 5 for this criterion.

Detailed rationale (optional):

Factor 4.1b Modifying factor: Mitigation of gear impacts

Scoring Guidelines
• +1 (Strong Mitigation)—>50% of the habitat is protected from fishing with the gear type. Or fishing intensity is very low/limited and for trawled fisheries, expansion of fishery’s footprint is prohibited. Or gear is specifically modified to reduce damage to seafloor and modifications have been shown to be effective at reducing damage. Or there is an effective combination of ‘moderate’ mitigation measures.
• +0.5 (Moderate Mitigation)—At least 20% of all representative habitats are protected from fishing with the gear type and for trawl fisheries, expansion of the fishery’s footprint is prohibited. Or gear modification measures or other measures are in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing that are expected to be effective.
• 0 (No Mitigation)—No effective measures are in place to limit gear impacts on habitats.
• 0 (Not Applicable) – Not applicable because gear used is benign and received a score of 5 in 4.1

Southern Ocean, midwater trawl

Key relevant information:
Score: 0 (gear does not contact the substrate)
Factor 4.2 Ecosystem-based Fisheries Management - Moderate Concern

Scoring Guidelines

- 5 (Very Low Concern) — Policies that have been shown to be effective are in place to protect species’ ecological roles and ecosystem functioning (e.g. catch limits that ensure species’ abundance is maintained at sufficient levels to provide food to predators) and effective spatial management is used to protect spawning and foraging areas, and prevent localized depletion. Or it has been scientifically demonstrated that fishing practices do not have negative ecological effects.

- 4 (Low Concern) — Policies are in place to protect species’ ecological roles and ecosystem functioning but have not proven to be effective and at least some spatial management is used.

- 3 (Moderate Concern) — Policies are not in place to protect species’ ecological roles and ecosystem functioning but detrimental food web impacts are not likely.

- 2 (High Concern) — Policies are not in place to protect species’ ecological roles and ecosystem functioning and the likelihood of detrimental food impacts are likely (e.g. trophic cascades, alternate stable states, etc.), but conclusive scientific evidence is not available for this fishery.

- 1 (Very High Concern) — Scientifically demonstrated trophic cascades, alternate stable states or other detrimental food web impact are resulting from this fishery.

Southern Ocean, midwater trawl

Key relevant information:
Antarctic krill is an important forage species for predators in the Southern Ocean. CCAMLR is broadly recognized as a progressive management entity for its incorporation of ecosystem-based management principles into its convention instead of having to move from a single-species to a multispecies approach (Constable 2011) (Nilsson et al. 2016). Article II of the Convention on the Conservation of Antarctic Living Marine Resources describes the ecosystem approach to fishery management and CCAMLR’s intention to maintain target stocks at productive levels and maintain species that are dependent and related. It also describes CCAMLR’s precautionary approach with respect to the krill stock (Constable 2011). The most prevalent concerns about ecosystem-based fishery management in this fishery are 1) the spatial resolution of management units, and 2) uncertainty about the performance of current fishery management rules in the face of climate change and potential expansion of the fishery.

CCAMLR has several management guidelines in place to protect predators from prey depletion, including setting catch limits to a fraction of the amount dictated by the trigger level and subdividing the management area into subareas. In 2003, CCAMLR agreed to the subdivision of management areas in 15 small-scale management units (SSMUs) based on the distribution of
krill, krill predators, and the fishery (CCAMLR 2015a) (Figure 6). But catch has not been allocated separately for each SSMU (CCAMLR 2015a). Area-specific trigger and catch limits are intended to protect predators from local depletion, and catch limits are conservative with the intent to leave enough krill biomass for predator needs in each subarea. Several studies have addressed ecosystem-based management objectives, using ecosystem models and studies of predator-prey interactions for the Antarctic krill fishery. But these studies have never been fully integrated into the decision-making process; instead, they provide context for current management strategies (Collie et al. 2016). Ecosystem models have not yet been used to determine fishing mortality. Currently, SC-CAMLR is using ecosystem models and fishery data to determine the optimal spatial scale of management for krill predators and to provide advice about subdividing krill catch in the southwest Atlantic (Constable 2011).

Future changes in the extent of sea ice and in melt time, along with increased participation in the fishery, could cause sweeping changes to food web structure and krill availability for predators. Low sea-ice extent is associated with years of poor recruitment for krill, which often causes decreases in total abundance (Fraser and Hofmann 2003). The current management plan for krill does not include any feedback for ensuring that ecosystem requirements are fulfilled, and CCAMLR could improve the robustness of its management plan by evaluating the risks and uncertainties of different possible impacts of climate change (Trathan and Agnew 2010). A major concern for the krill fishery is that climate change will cause a regime shift that will make the population vulnerable even at the current catch levels.

Although CCAMLR’s management scheme follows the principles of EBFM, CCAMLR has not yet defined operational objectives for ecosystem-based management of the krill fishery (Cavanagh et al. 2016). Because detrimental impacts on the food web are possible due to krill’s importance as a forage species but the policies that are currently in place may not be robust to respond to future changes in the fishery, Seafood Watch considers krill to be of “moderate” concern for Ecosystem-Based Fisheries Management.

Detailed rationale (optional):

Krill is a key forage species for predators in the Southern Ocean and is preyed upon by finfish, albatross, penguins (chinstrap, Adélie, emperor, gentoo, macaroni, king, and rockhopper), and marine mammals (baleen whales, as well as fur, crabeater, Weddell, elephant, and leopard seals). These are mostly spatially restricted foragers, which feed in the same areas where the krill fishery occurs (Watters et al. 2013). They also have significant needs in terms of krill biomass: a study by Hill et al. (2007) found that fish consume more krill than do penguins and whales combined. Because of the importance of krill to predator diets, CCAMLR has included ecosystem considerations in its management objectives, and biological models that include spatial considerations have been developed to examine the impacts of local prey depletion on predators (e.g., Plaganyi and Butterworth 2012). CCAMLR uses diet composition and other indicators to detect changes in the relative consumption of krill by predators (CCAMLR 2015a).
Estimates of predator-prey interaction strength have been considered highly uncertain, so this information is currently used by CCAMLR only to provide context for other management decisions, and CCAMLR has not yet defined predator reference points.

Although the catch limit for krill is precautionary for each management area in the Southern Ocean, much of the fishing for krill occurs in a relatively small area (Area 48), and localized depletion is a concern for predators, including fish, penguins, and whales. In recognition of this possibility, CCAMLR has a “trigger level” (currently set at 620,000 MT, or the maximum combined historic catch), above which the fishery cannot proceed without an agreed-upon mechanism to distribute catches more evenly among the subareas. Each season, catches in any one subarea are not allowed to exceed 25% of the trigger level (a defined percentage for Subarea 48.1, 45% for Subarea 48.2, 45% for Subarea 48.3, and 15% for Subarea 48.4). In 2003, CCAMLR agreed to a subset of small-scale management units (SSMUs) within Area 48 that are based on the distribution of krill and krill predators (Figure 6). Although these units have been established, there has not been agreement on the allocation of catches at that scale. Spatial allocations of catch have been demonstrated to be less sensitive to choices of predator reference points and predator groupings; however, high certainty around predator reference points and predator groupings may not be necessary in order to have effective spatial management (Hill 2013b).

The central debate in krill fishery management recently has been the spatial allocation of trigger levels. Subarea 48.1 is a good example of this debate. The trigger limit for Subarea 48.1 has been reached several times in the past 5 years, and the krill fishery was closed each time—without Conservation Measure 51-07, the fishery would have continued fishing in this relatively small area. But the majority of the catch within Subarea 48.1 was taken from the Bransfield Strait, suggesting that trigger limits may need to be set at an even more local scale. There is currently a debate within CCAMLR as to whether having trigger biomass distributed at the subarea scale is sufficiently precautionary.

The CCAMLR Ecosystem Monitoring Program (CEMP) was established in 1985 to detect changes in the krill-based ecosystem in the Southern Ocean, in order to provide recommendations for an “ecosystem approach” to management. The program is intended to “detect and record significant changes in critical components of the ecosystem” and to “distinguish between changes due to the harvesting of commercial species and changes due to environmental variability, both physical and biological” (CCAMLR 2015a). Despite this solid institutional basis for EBFM, there are several areas in which CCAMLR can improve the implementation of EBFM and include ecosystem objectives in its decision of catch limits.

The association of krill with sea ice makes krill particularly vulnerable to climate change, specifically changes in the timing and extent of sea ice in the Antarctic. Krill tends to congregate in the Bransfield Strait during the winter, an area that is becoming ice-free more frequently. This makes them more vulnerable to fisheries in the autumn and winter (Jones et al. 2015), where they are heavily targeted (CM 51-07 is designed to prevent local depletion, and the Bransfield Strait is one place where localized depletion is a concern). Additionally, predators
such as chinstrap and Adélie penguins are likely to face additional pressure when ocean warming combines with increases in the abundance of their competitors for krill in coming years (Trivelpiece et al. 2011). The Scientific Committee has agreed that climate change and the ensuing changes in water temperature and ice melt timing are important to consider when producing recommendations for the Commission (Jones et al. 2015).

Figure 6: This image and caption are reproduced from Flores et al. (2012). (A) Circumpolar distribution of post-larval Antarctic krill (re-drawn from Atkinson et al. 2008). The plot shows arithmetic mean krill densities (ind. m$^{-2}$) within each 5° latitude by 10° longitude grid cell derived from KRILLBASE. (B) CCAMLR convention area, with FAO statistical Subareas 48.1 to 88.3. (C) Trends of change in ice season duration between 1979 and 2006 in d yr$^{-1}$ (provided by E. Maksym, British Antarctic Survey). Trends were calculated from satellite-based daily sea ice concentration data provided by the National Snow and Ice Data Center (University of Colorado at Boulder, http://nsidc.org), using the methodology described by Stammerjohn et al. (2008). (D) Trend of midwater ocean temperature change during the period 1930 to 2000 in °C yr$^{-1}$ (modified from Gille 2002, with permission). The analysis was based on archived shipboard
measurements (1930–1990) and Autonomous Lagrangian Circulation Explorer (ALACE) float data (1990–2000) from 700 to 1100 m depth (© American Association for the Advancement of Science 2002).
Acknowledgements

Scientific review does not constitute an endorsement of the Seafood Watch® program, or its seafood recommendations, on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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