



## REVIEW OF ARCTIC COD (*BOREOGADUS SAIDA*) BYCATCH IN CANADIAN ARCTIC SHRIMP FISHERIES



Arctic Cod (*Boreogadus saida*).

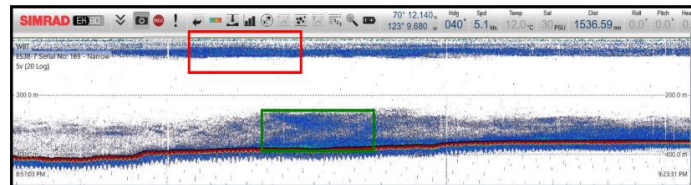


Figure 1. Echogram recorded with SIMRAD EK-80 acoustic system (38 kHz) at a 353 m station in the Amundsen Gulf. The red rectangle (top) indicates a subsurface aggregation of young-of-the-year fish, while the green rectangle (bottom) indicates a benthic aggregation of larger individuals. Note the vertical extension (thickness, 80–100 m) of each of the aggregations in contrast to the sampling capacity of fishing gear (few meters vertical opening). Courtesy of Andy Majewski (DFO, data unpublished).

### Context:

*Incidental bycatch and discard of non-targeted species occur in many fisheries. An objective of an Ecosystem Approach to Fisheries Management is to control incidental mortality of non-targeted species. Arctic Cod (*Boreogadus saida*) is a ubiquitous species occurring in a wide range of habitats in the Arctic. Given this widespread distribution and tendency to form large aggregations, it is a common bycatch species in various northern fisheries including the Northern and Striped Shrimp fisheries in the Eastern Canadian Arctic.*

*Fisheries and Oceans Canada (DFO) Resource Management requested that DFO Science provide advice on a sustainable overall bycatch limit of Arctic Cod (in tonnes) for Shrimp Fishing Area 1 and the Eastern and Western Assessment Zones (EAZ and WAZ) as well as establishing suitable references to indicate when that mortality is unacceptable. In providing the requested advice, DFO Science was asked to consider the current “move away” provision on commercial licences.*

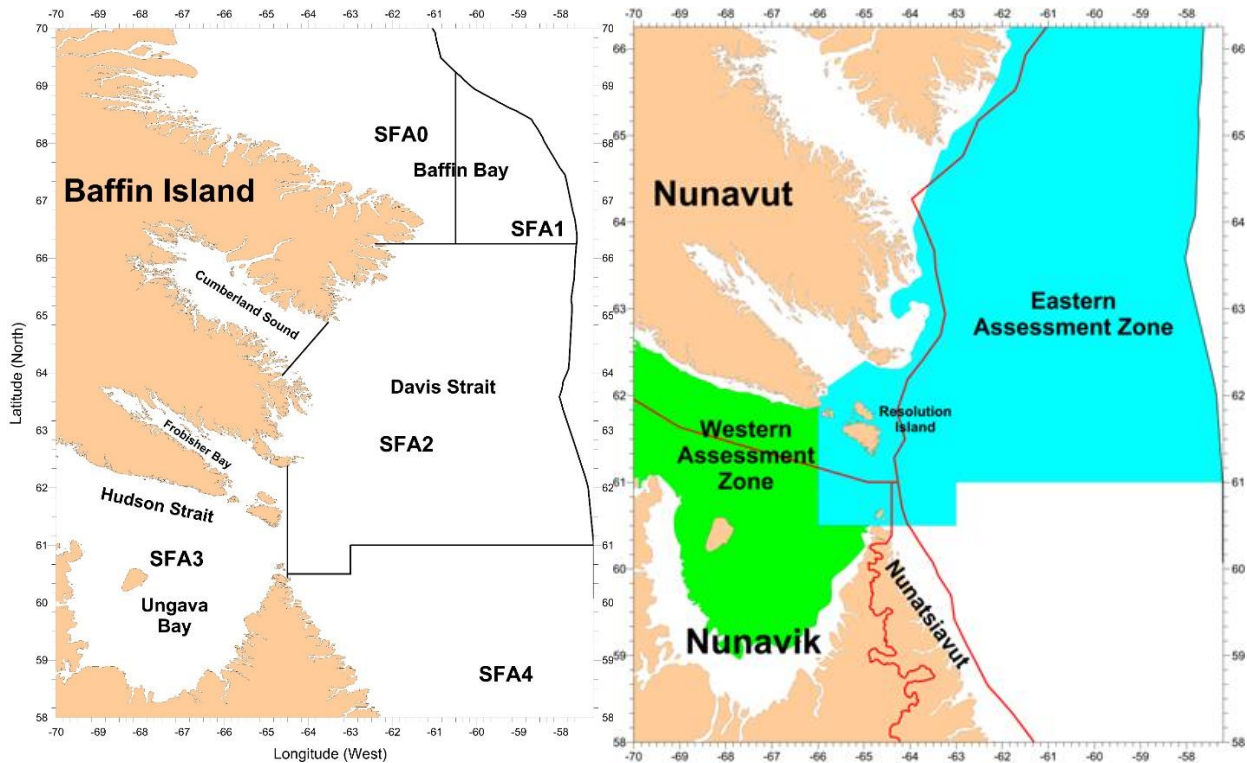
*This Science Advisory Report is from the July 3–4, 2019 meeting on Advice on Arctic Cod (*Boreogadus saida*) Bycatch Limits in Northern Shrimp Fisheries in the Canadian Arctic. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.*

## SUMMARY

- The shrimp fishery in the Canadian Arctic is an important resource for Inuit of Nunavut and Nunavik and the commercial shrimp industry in Shrimp Fishing Area 1 (SFA 1) and the Eastern and Western Assessment Zones (EAZ/WAZ). In general, a positive correlation between the total shrimp catch and Arctic Cod (*Boreogadus saida*) bycatch has been observed.
- Due to insufficient data, Science Advice could not be provided in regards to a “cap” for Arctic Cod removal and specifications of the “move away” provision.
- Due to the scarcity of data and the patchy spatial and temporal distribution of Arctic Cod, there is high uncertainty in the biomass index estimates obtained from the surveys that are not designed to target Arctic Cod. This uncertainty leads to low confidence in determining the impacts of Arctic Cod removal by the shrimp fishery. If the biomass index estimates are considered accurate, then the percentage of Arctic Cod removed from the total biomass is likely very low but given the high uncertainty, precaution is advised.
- The absence of a dedicated survey and the limited data on life history of Arctic Cod preclude the use of the Guidance Related to Bycatch and Discards in Canadian Commercial Fisheries (DFO 2012) to determine a sustainable catch limit.
- Canada is committed domestically and internationally to implementing conservation and management measures to address incidental bycatch, including Arctic Cod in the Northern and Striped Shrimp fisheries in the Eastern Canadian Arctic.
- Arctic Cod is a small bodied, short-lived forage fish with an atypical life history for gadoids as it occupies the pelagic zone for a portion of its life beyond the larval and juvenile stages. Despite these characteristics, Arctic Cod is specified as groundfish in the Atlantic Fishery Regulations and therefore “move away” provisions in the offshore Northern shrimp Conditions of Licence apply.
- Arctic Cod transfers energy from lower to higher trophic levels and thus is considered a pivotal species in the Arctic marine ecosystem, providing food for numerous species of seabirds, marine mammals, and fishes. A substantial total biomass of Arctic Cod is required for ecosystem maintenance.
- Arctic Cod have a circumpolar distribution and are considered seasonal migrants that use different habitats throughout the year (e.g., summer aggregations, under-ice habitat use).
- Continued reporting of both target and bycatch species from the At-Sea Observer program and vessel logbooks will be necessary to provide future Science Advice regarding any species caught in this fishery.
- Dedicated research is needed on Arctic Cod biology, ecology, population dynamics, and ecosystem modelling to better understand their pivotal role in the food web. This would also allow for greater certainty in biomass index estimates to improve Science Advice on sustainable bycatch removals by the shrimp fishery.

## INTRODUCTION

The shrimp fishery in the Eastern Arctic operates in Shrimp Fishing Areas 1–3 (SFA 1–3; Figure 2). SFA 1 is located in Northwest Atlantic Fisheries Organization (NAFO) Division 0A within Baffin Bay and SFA 2 falls within Davis Strait. For the purpose of the shrimp stock assessment process, SFA 2 is analogous to the EAZ (Eastern Assessment Zone) (DFO 2017). SFA 3 is located in Hudson Strait and is analogous to the WAZ (Western Assessment Zone). The fishery in SFA 1 operates on a calendar year basis (i.e., January 1 to December 31). Historically, SFAs 2 and 3 were also managed on a calendar year basis, however, a new policy was adopted in 2003 that implemented a fiscal year management cycle (i.e., April 1 to March 31).



*Figure 2. Location of Shrimp Fishing Areas (SFAs) used until 2013 and Western and Eastern Assessment Zones used since 2013.*

Since 2017, shrimp fishing vessels operating in Shrimp Fishing Areas 1 (Baffin Bay) and 3 (Hudson Strait), have occasionally reported large amounts (400–2,300 kg per tow) of Arctic Cod bycatch. In Eastern Canada, Arctic Cod is listed as a groundfish species ([Atlantic Fishery Regulations 1985](#)), which means that elevated amounts of Arctic Cod bycatch can trigger a standard “move away” provision, as per the [Northern and Striped Shrimp Conditions of Licence](#), which states: “*In the event that the total incidental catch of all groundfish species in any set exceeds the greater of 2.5% or 100 kg total weight, the licence holder/operator must immediately change the vessel’s fishing area by a minimum of 10 nautical miles from any coordinate during the last tow*”.

High occurrences of Arctic Cod bycatch, while not common, pose a significant burden on the fishing industry and have unknown ecological consequences. With limited time to harvest the allotted shrimp catch each year due to the relatively short open-water period and long transit

times from southern ports of origin, the fishing industry in the Eastern Arctic has asked DFO Resource Management for increased flexibility in Arctic Cod bycatch, with “move away” provisions triggered by the amount of Arctic Cod bycatch averaged over a number of consecutive tows rather than triggered by the amount of bycatch in one tow.

As a result, DFO Resource Management approached DFO Science seeking Science Advice on ecologically and biologically-responsible Arctic Cod removal levels in individual Shrimp Fishing Areas (SFAs). Given the absence of a comprehensive Arctic Cod stock assessment, the purpose of this process is to discuss ecologically and biologically acceptable levels for Arctic Cod removals in SFA 1, EAZ, and WAZ and whether it is possible to identify a “cap” for the total annual bycatch level of Arctic Cod for the three areas.

### **Arctic Cod Biology**

Arctic Cod is a relatively small fish ([mean size: 140 mm, maximum size: 400 mm](#); Matley et al. 2013) with a maximum life span of seven years. Arctic Cod spawns in winter (Hop et al. 1995) and the larvae hatch between April and June depending on geographical location (Bouchard and Fortier 2011). Larval Arctic Cod feed initially on smaller prey items (e.g., *Copepoda nauplii*, Rotifers) and prey on larger items as they grow (e.g., *Calanus copepods*; Walkusz et al. 2011). Juvenile fish (~35 mm in length) feed on copepods. After reaching the size of descent (~50 mm; Falk-Petersen et al. 1986, Majewski et al. 2016), Arctic Cod adopts a demersal life and, in addition to *Calanus* copepods, starts feeding on amphipods and fishes, including cannibalism. Once associated with the bottom, Arctic Cod becomes part of the demersal community, along with Northern and Striped Shrimp, and is incidentally caught in the shrimp fishery.

## **ASSESSMENT AND ANALYSIS**

### **Arctic Cod Historical Catches**

All vessels fishing for shrimp in the Eastern Canadian Arctic are required, as a condition of their licence, to have an At-Sea Observer (ASO) present on board at all times (i.e., 100% observer coverage). Data on bycatch (e.g., species caught, total weight caught for each species, measurements from individual animals) are collected by dedicated personnel (ASO) during shrimp fishing trips. Data collected by ASO are independent from the fishery records (logbooks) kept by the vessel’s captain and include information about both the target and bycatch species. Based on the data collected by ASO, Walkusz et al. (2020a) found a positive correlation (with the exception of SFA 2 where no correlation was established) between the amount of shrimp caught and the amount of Arctic Cod bycatch.

The fishery does not retain the incidentally caught Arctic Cod, thus, contrary to other fisheries in which bycatch is landed, the shrimp fishery returns the biomass to the sea. However, since the commercially executed fishing tows are 2–3 h in duration, the survival of released Arctic Cod is expected to be low.

### **Arctic Cod Population Biomass Estimates**

Arctic Cod is considered a schooling fish (Hop et al. 1997), however, “aggregating fish” seems a more appropriate term considering the dense aggregations of different size/age individuals and non-unidirectional movement observed by Geoffroy et al. (2011, 2016; Figure 1). Arctic Cod is often dispersed throughout the water column and is therefore hard to properly quantify using any one type of directed sampling gear (either demersal or pelagic).

A biomass index of bottom-dwelling Arctic Cod was estimated using data from scientific surveys. Available data were combined from surveys targeting Northern and Striped Shrimp (200–600 m depth range) and groundfish, in particular Greenland Halibut (400–1,500 m depth range). The groundfish surveys conducted by DFO in Div. 0A (SFA 1) and Div. 0B (SFA 2) used an Alfredo III trawl with 20 mm cod-end mesh. Groundfish surveys are not conducted in SFA 3. Initial stock assessment (2006–2013) surveys for Northern and Striped Shrimp in SFA 3 were conducted by DFO with a Cosmos trawl with 12.8 mm cod end mesh. Since 2006 in SFA 2 and 2014 in SFA 3, surveys were designed by DFO and conducted by the Northern Shrimp Research Foundation (NSRF) using a Campelen 1800 trawl with 12.8 mm cod end mesh. All of the aforementioned surveys are strictly demersal and lack information on pelagic zone.

The results of these demersal surveys were used to quantify Arctic Cod biomass in SFAs 1–3, which resulted in an estimated biomass index that does not exceed 70,000 t in all SFAs combined (Walkusz et al. 2020b; Figures 3–5). This estimate likely represents a greatly underestimated index because of the scarcity of data, the patchiness of Arctic Cod occurrence, and the fact that only the demersal component of the ecosystem was sampled during the surveys.

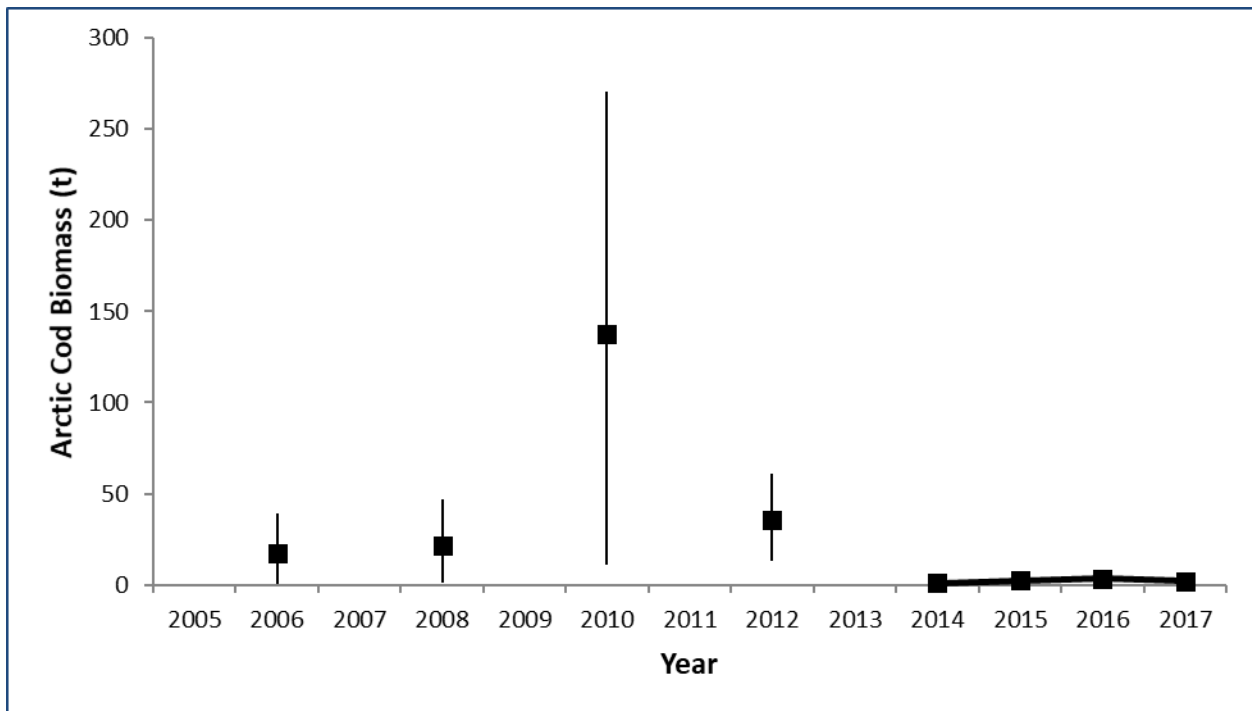


Figure 3. Biomass index of bottom-dwelling Arctic Cod from the DFO Groundfish Survey in Div. 0A (SFA 1) for 2005–2017. Bars indicate standard deviation of the Arctic Cod biomass index. Note that the scale of Arctic Cod Biomass differs between SFAs (i.e., Figures 3–5).

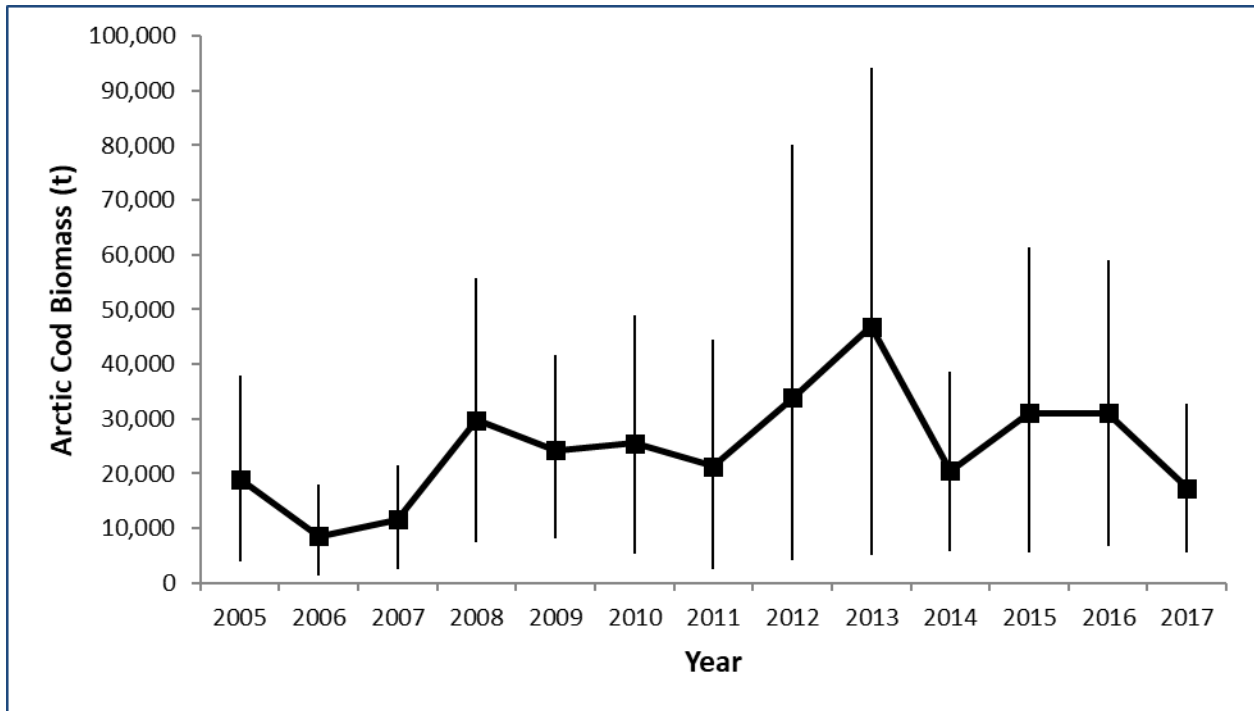


Figure 4. Biomass index of bottom-dwelling Arctic Cod from the Northern Shrimp Research Foundation (NSRF) survey in SFA 2 for 2005–2017. Bars indicate standard deviation of the Arctic Cod biomass index. Note that the scale of Arctic Cod Biomass differs between SFAs (i.e., Figures 3–5).

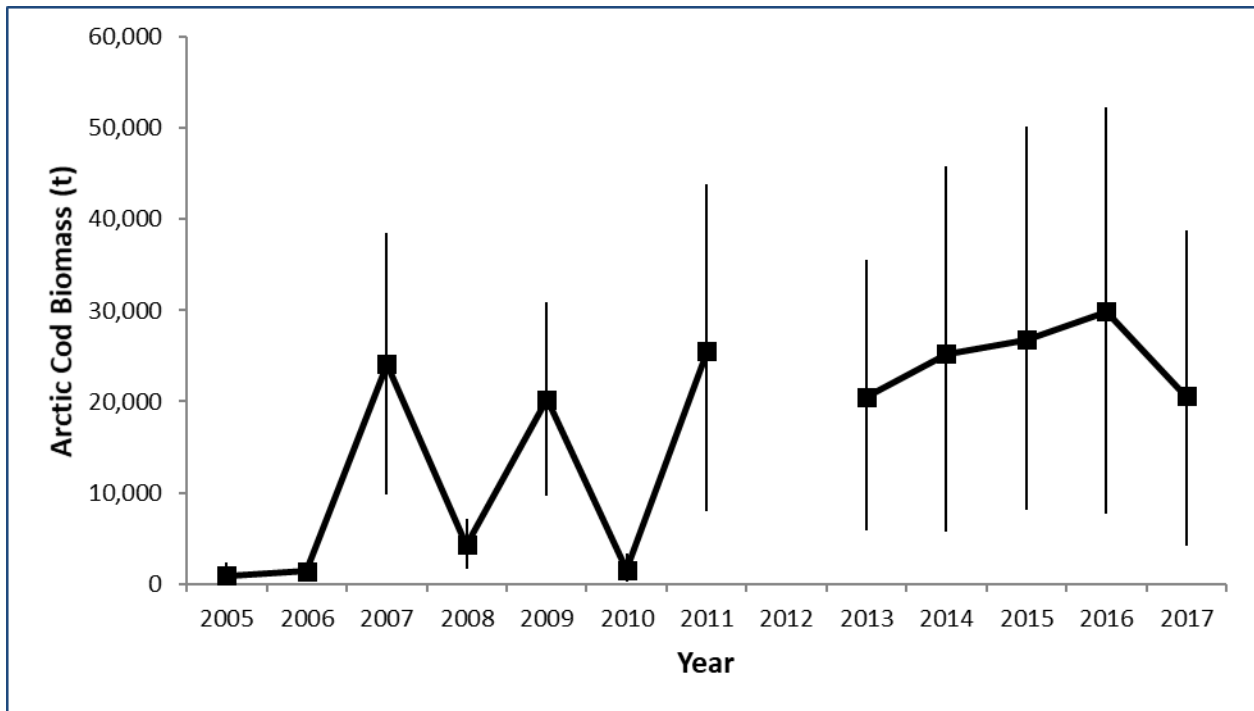


Figure 5. Biomass index of bottom-dwelling Arctic Cod in SFA 3 from the NSRF survey for 2005–2017. Bars indicate standard deviation of the Arctic cod biomass index. Note that the scale of Arctic Cod Biomass differs between SFAs (i.e., Figures 3–5).



This underestimation most likely stems from the fact that Arctic Cod is a pelago-benthic fish and an unknown portion of its population may reside in the water column during the survey. Since Arctic Cod tend to aggregate, the surveys may not detect the aggregations because a given survey is a “snap-shot” of fish biomass at a specific time as opposed to an active tracking approach. Finally, Arctic Cod migrations are poorly understood in the Canadian Eastern Arctic, which can lead to surveys missing large cohorts of fish at certain times of the year.

By using recent estimates for fish, bird, seal, and whale populations in Baffin Bay/Davis Strait, Walkusz et al. (2020b) found that the Arctic Cod biomass requirement for ecosystem maintenance is > 500,000 t Arctic Cod annually. While this approach most likely produced a conservative estimate of the Arctic Cod biomass required to sustain its predators, it provides a general estimate of the order of magnitude of the Arctic Cod biomass required by the ecosystem.

### **Sources of Uncertainty**

#### **Overall lack of knowledge of Arctic Cod biology in the areas of interest.**

While the general biology of Arctic Cod has been studied extensively in various Arctic locations, its biology is poorly understood in the geographic areas considered in this review. The lack of information on the timing of descent of juvenile Arctic Cod from pelagic to benthic habitats (i.e., when they become susceptible to fishing mortality in the shrimp fishery) represents therefore a significant knowledge gap. Multi-seasonal sampling along with length analyses of individuals caught would provide an insight into the ontogenetic timing of vertical migrations of Arctic Cod.

#### **Insufficient data collection for biomass index analysis.**

In this analysis, the biomass index was based solely on the benthic catches; however, Arctic Cod is considered a pelago-benthic species. Consequently, the lack of information on the pelagic portion of the population likely leads to significant underestimates of the Arctic Cod biomass. Application of acoustic methods (e.g., echosounder) along with pelagic trawl sampling would address this knowledge gap.

#### **Insufficient data on distribution and abundance of Arctic Cod predators.**

Analysis of predation pressure on Arctic Cod was conducted using published abundances of predators with the assumption that a portion of the predator population (i.e., 10%) would be present in the areas of interest. Using this assumption, the biomass of Arctic Cod required to sustain its predators was estimated. While this generalization provides some insight into Arctic Cod abundance, it is not a direct measure of fish biomass and the uncertainty associated with this approach is significant.

#### **Potential observer data bias.**

All offshore vessels operating in the areas of interest are obliged by the Conditions of Licence to have an At-Sea Observer (ASO) onboard. The data collected by the ASO is meant to be fishery independent; however, it can be expected that particular tows are not monitored due to the limitations of having only one ASO onboard, which may create an underestimation bias in the information reported.

## **CONCLUSIONS AND ADVICE**

Considering the relatively small total fishing mortality of Arctic Cod stemming from the bycatch of the Northern shrimp fishery in the Eastern Canadian Arctic, i.e., less than 0.1% of the estimated Arctic Cod stock annually as estimated using predators' requirements, it can be assumed that the impact of the shrimp fishery on the Arctic Cod population is minimal in each of the three areas.

**Central and Arctic Region**

Consequently, bycatch mortality is unlikely to result in negative ecosystem impacts (i.e., predator requirements). However, given the high uncertainty in the Arctic Cod biomass index estimates, precaution is advised. Given the scarcity of data, Science cannot currently provide an ecologically and biologically acceptable Arctic Cod bycatch removal limit for the areas of interest.

Considering the methods used in shrimp fishery (e.g., length of the tow, characteristics of the fishing gear, processing of the catch), the probability of survival for incidentally caught Arctic Cod is low.

A dedicated sampling program to learn more about the species' biology and an acoustic survey to study the spatial and temporal distribution of Arctic Cod is strongly recommended to better inform future management decisions.

**LIST OF MEETING PARTICIPANTS**

All participants at this science peer review meeting are expected to participate as objective and knowledgeable individuals on the subject matter under review; not advocates or representatives of any interest group.

Name	Organization/Affiliation
Eva Enders (Chair)	DFO – Science, Central and Arctic Region
Joclyn Paulic	DFO – Science, Central and Arctic Region
Shelia Atchison	DFO – Science, Central and Arctic Region
Sheri Friesen	DFO – Resource Management, Central and Arctic Region
Hannah Murphy	DFO – Science, Newfoundland and Labrador Region
David Deslauriers	DFO – Science, Central and Arctic Region
Susan Thompson	DFO – Science, National Capital Region
Robert Moshenko	Nunavik Marine Region Wildlife Board
Amber Giles	Nunavut Wildlife Management Board
Leigh Edgar	DFO – Resource Management, National Capital Region
Ross Tallman	DFO – Science, Central and Arctic Region
Wojciech Walkusz	DFO – Science, Central and Arctic Region

**SOURCES OF INFORMATION**

This Science Advisory Report is from the July 3–4, 2019 meeting on Advice on Arctic Cod (*Boreogadus saida*) Bycatch Limits in Northern Shrimp Fisheries in the Canadian Arctic. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

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ISSN 1919-5087

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Correct Citation for this Publication:

DFO. 2020. Review of Arctic Cod (*Boreogadus saida*) bycatch in Canadian Arctic Shrimp Fisheries. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/007.

*Aussi disponible en français :*

*MPO. 2020. Examen des prises accessoires de morue arctique (Boreogadus saida) dans les pêches à la crevette de l'Arctique canadien. Secr. can. de consult. sci. du MPO, Avis sci. 2020/007.*