Wednesday, April 27, 2022

A FULLER PICTURE OF THE STATE OF CANADA'S FISHERIES: ASSESSMENTS FOR DATA-LIMITED STOCKS

By Rebecca Schijns

OCEANA Protecting the World's Oceans

Contents

Executive Summary

To maintain healthy Canadian fish populations for future generations, it is important to know their health status so that management measures, such as harvest levels and limits, can be adjusted to reflect best practices. Unfortunately, the stock statuses for more than a third of Canada's fisheries are uncertain. These knowledge gaps can have far-reaching impacts on Canadian fisheries and the prospects of rebuilding abundant marine ecosystems. This research uses a widely accepted assessment tool designed to overcome data limitations and estimate stock status to provide a fuller picture of the state of Canada's fisheries. Around a hundred fish stocks were examined in this approach, resulting in 84 new stock assessments. With the inclusion of new assessments, Canadian fisheries consist of 40% healthy stocks, 29% cautious stocks, 25% critical stocks, and 6% uncertain stocks. Assigning health status to fisheries which were previously left in an 'uncertain' state will help the federal government prioritize policy and management decisions that benefit marine ecosystems as well as coastal communities that depend on marine resources.

Glossary

Bayesian method	An assessment method which quantifies uncertainties and provides advice based on the probability of reaching a limit or target point.
Carrying capacity (*k*)	The maximum population an environment can support, expressed in tonnes.
Depensation	The reduction of recruitment at very low population sizes, as a result of declining recruits per spawner, increased natural mortality, or both, expressed by a linear decline of *r* below *k/4*.
Intrinsic population growth rate (*r*)	Maximum net productivity of a population, calculated by the number of births minus the number of deaths per generation time.
Limit Reference Point (LRP)	The point that delineates between the cautious and critical zone, below which serious harm is occurring to the stock and may negatively impact the associated ecosystem and fishing community. Often expressed as 40% of B_{MSY}.
Model	A tool to represent a real phenomenon that is difficult to observe directly and used to explain and predict the behaviour of real objects or systems.
Precautionary Approach	A Canadian policy within the Sustainable Fisheries Framework that aims to manage threats of serious or irreversible harm where there is scientific uncertainty. The guiding principles express being cautious when scientific knowledge is uncertain, and not using the absence of adequate scientific information as a reason to postpone action or failure to take action to avoid serious harm to fish stocks or their ecosystem.
Parameter	A constraint (such as *r* and *k*), with variable values, used as a referent for determining other variables
Prior	Initial beliefs about an event in terms of probability distribution.

Prior density	Information about an uncertain parameter that is combined with the probability distribution of new data to generate a posterior distribution, which is used for future inferences.
Maximum Sustainable Yield (MSY)	The largest average catch or yield that can continuously be taken from a stock under existing environmental conditions.
Stock	A population from which catches are taken in a fishery and which is more or less isolated from other stocks of the same species and thereby self-sustaining.
Stock assessment	The scientific process of analyzing available data to describe what is known about the state of a stock and evaluate the expected impacts and benefits of proposed fisheries management measures.
Sustainable Fisheries Framework	A suite of policies which provides the basis for ensuring that Canadian fisheries support conservation and sustainable use of resources, including precautionary and ecosystem-based approaches.
Surplus-production	The principle whereby fish populations, on the average, produce more offspring than necessary to replenish themselves. Thus, on the average, fisheries should be able to harvest this excess (surplus) production without endangering the population.
Target Reference Point (TRP)	The stock size that meets productivity objectives for the stock, broader biological considerations, and social and economic objectives for the fishery. Often expressed as a stock size close to B_{MSY}.
Upper Stock Reference (USR)	The point that delineates between the cautious and healthy zone, below which removals must be progressively reduced in order to avoid reaching the LRP. Often expressed as 80% of B_{MSY}.

Introduction

Throughout its history, the Canadian government has failed to manage many important commercial fisheries resources in an effective manner based on conflicting objectives and the "race for the fish" (Parsons, 1993), the consequences of which are still felt today from major commercial fishery closures and declining annual catches. The extent of loss from the oceans remains largely unknown since many fisheries are perceived as data deficient and therefore are not assigned a health status. Consequently, such fish and invertebrate populations continue to be exploited while lacking protection from regulatory and legal obligations. The Canadian government has the opportunity to break past patterns of delayed protection and discounting relevant scientific information (Castañeda et al., 2020) by building the capacity of science-based fisheries management and applying new widely available tools (Palomares et al., 2021) that are designed to overcome data limitations.

The implementation of the Precautionary Approach in the Sustainable Fisheries Framework in 2009 marked a significant milestone in fisheries management for the Fisheries and Oceans Canada (DFO, 2009). This policy includes measures to set target and limit reference points to allow time for managers to react to unexpected changes and prevent overfishing. In addition to adopting Precautionary Approach principles domestically, the Canadian government has made commitments internationally through the United Nations Agreement on Straddling and Highly Migratory Fish Stocks (UN, 1995) and the Food and Agriculture Organization Code of Conduct for Responsible Fishing (FAO, 1995). As part of the national framework, all major Canadian fish stocks will be assessed with well-defined reference points, as necessary, to classify their current stock status and guide fisheries management actions. Recent amendments to the *Fisheries Act* (Lafrance and Nguyen, 2018) require rebuilding plans for prescribed stocks that are depleted below limit reference points. As of April 2022, rebuilding plans for prescribed critical stocks must be compliant with the new rebuilding regulations published in *Canada Gazette*, Part II (*Canada Gazette*, Part II, 2022). These measures include defining explicit targets and timelines for rebuilding major fish stocks.

To determine the status of marine fisheries and manage objectives such as rebuilding stocks and maintaining sustainable yields, it is essential to have both target and limit reference points. Targets are stock size and fishing mortality levels that managers aim to achieve and maintain, while limits denote levels to avoid (Cooper, 2006). Measuring where a stock lies in relation to targets and limits guides what type of management action will occur. Based on international practices and standards, the reference point B_{MSY} is adopted for comparing the health of fish stocks (UN, 1995) and describes biomass (or weight of the fish population in the water) capable of generating Maximum Sustainable Yield

(MSY). In Canada, an upper stock reference (USR) identifies the boundary above which a fishery can be considered healthy ($B_t \geq$ USR), while a limit reference point (LRP) identifies the boundary below which it can be considered to be in a critical state ($B_t \leq$ LRP). Ideally, corrective action should be taken before a stock reaches the limit reference point. The LRP and USR are often expressed as 40% of B_{MSY} and 80% of B_{MSY} (Figure 1).

In 2017, Oceana Canada initiated the annual Fishery Audit to assesses the current state of Canada's fisheries and fisheries management in accordance with federal policy commitments. Over the past five years, three main problems were consistently identified with the management of Canadian fisheries: declining fisheries, data gaps and the slow pace of stock rebuilding (Oceana, 2017; 2018; 2019; 2020; 2021). According to the latest Fishery Audit, more than a third of Canada's fisheries have missing data and are categorized as 'uncertain' status, making it difficult to ensure populations are sustainably managed at healthy levels and avoid critical depletion or overfishing (Oceana Canada, 2021). The progress towards successfully implementing the Precautionary Approach has been slow (Hutchings et al., 2012a), and without quantifiable targets, sustainable fisheries policies could be weakened by ambiguity (Hutchings et al., 2020; Winter and Hutchings, 2020).

Stock assessments have been adopted as the primary tool to determine stock status, develop management objectives and set quotas. Catch, abundance and biological information are the three main data types fed into models that describe changes over time to make predictions about how a population responds to different management options. However, traditional stock assessments are often data-intensive (requiring parameters like length, age, size, maturity etc.), expensive[1], time-consuming and focused on commercially important, higher trophic level species (Rice and Rivard, 2002; Ricard et al., 2012). Many other stocks continue to be fished while their status is unknown (Winter and Hutchings, 2020). Fisheries managers are then faced with making decisions like assigning quotas without necessarily having a scientific baseline for assessing changes from historical periods to current population levels (Anderson et al., 2008; Mercer, 2013).

Although many fisheries are regarded as 'data-poor' and not eligible for traditional stock assessments, there is often valuable information available that can be used in alternative approaches. Indeed, some newly developed assessment methods that are designed for data-limited situations can use information such as catches, which is one of the most widely available and affordable types of fishery data.

[1] Stock assessments that use fishery-independent data from research surveys or scientific cruises can cost around 50,000 USD to millions of dollars per stock (Pauly et al. 2013) and are rarely conducted in economically developing countries due to their costly nature (Khalfallah, 2020).

These methods can be applied to the almost one hundred stocks exploited by commercial fisheries in Canada, whose status is currently categorized by DFO as 'uncertain' status, and which lack reference points.

In this analysis, a newly developed data-limited stock assessment model, named CMSY++ (Froese et al., 2019), is used along with nationally reported catches and available biomass estimates to assign provisional stock statuses according to the Precautionary Approach (DFO, 2009). This approach is updated and improved from its predecessors, CMSY (Froese et al., 2017) and Catch-MSY (Martell and Froese, 2013). Since it was first published, the CMSY model has been widely applied and documented in around 60 scientific peer-reviewed publications and CMSY++ has been applied to over 2,000 stocks around the world (Palomares et al., 2021). In Canada, the CMSY tool has been used to assess 97 stocks in Canadian Atlantic, Arctic and Pacific oceans (Schijns, 2020), as well as a 512-year long assessment of Eastern Canada's iconic northern cod *Gadus morhua* (Schijns et al., 2021).

The original method, Catch-MSY (Martell and Froese, 2013), has also been used in official Canadian reports for data-limited stocks such as big and longnose skate (*Raja binoculata and R. rhina*) where DFO states, "Of the three approaches attempted, the Catch-MSY approach provided the most encouraging results" and "This approach may work well for elasmobranchs and should be investigated in the future for other species with similar life history constraints" (King et al., 2015). However, the report also notes concerns over the sensitivity to assumptions and recommends the results be used as guiding harvest levels rather than specific harvest advice (King et al., 2015). In another case, reference points for three Arctic char (*Salvelinus alpinus*) management units were calculated using the Catch-MSY approach (DFO, 2018). So far, DFO has not published assessments using CMSY or CMSY++ approaches (Froese et al., 2017, 2019), although both methods address several deficiencies of previous iterations. When compared with estimates of independent, traditional stock assessments, these methods yield comparable results, and thus can be viewed as reliable alternatives in data-limited situations (Froese et al., 2017; 2018, Palomares et al., 2021).

This research explores the potential value of using timely, data-limited approaches to assign previously 'uncertain' stocks with current status estimates, thus filling data gaps identified in Oceana Canada's Fishery Audit. By assigning health status to fisheries that would otherwise be left in the 'uncertain' category, Canada will be better able to prioritize policy and managed decisions that support the long-term health of the fishery. Knowing the health status of a fishery, even a provisional one, is critical to making fisheries decisions that support healthy oceans and thriving coastal communities. Ultimately, the goal is to help Canada's progress towards fulfilling national and international commitments to rebuilding fisheries and sustaining marine biodiversity.

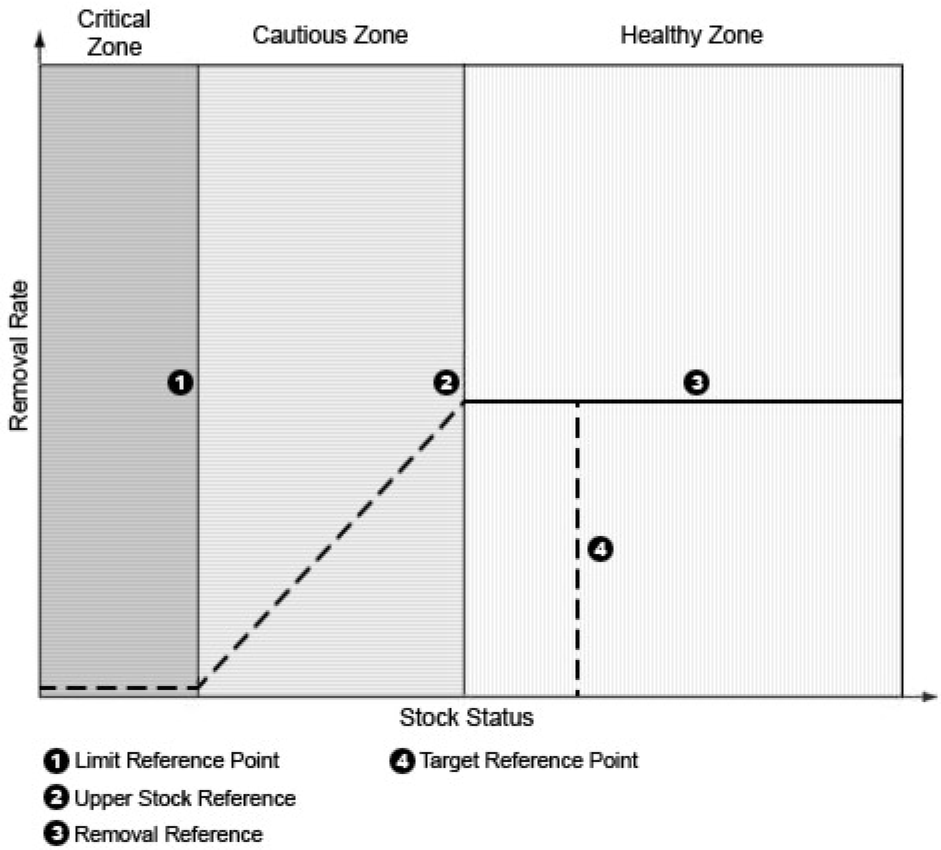

Figure 1. Stock status zones and reference points from the Sustainable Fisheries Framework incorporating the Precautionary Approach (DFO 2009). Zones are defined as healthy (biomass ≥ 80% B_{MSY}), cautious (40% B_{MSY} < biomass < 80% B_{MSY}), or critical (biomass ≤ 40% B_{MSY}). In the healthy zone, Target Reference Points can (and should often) be developed above the Upper Stock Reference.

Methodology

CMSY++ stock assessment

To derive biomass trends over time, we used the most recent version[2] of CMSY++ (Froese et al., 2019; in review) based on the now well-established and globally documented data-limited 'Catch Maximum Sustainable Yield' (CMSY) method, originally proposed by Martell and Froese (2013) and improved by

[2] In response to feedback from its users, the CMSY code has been updated in a number of ways including, but not limited to: an option to consider degree of technological creep (Palomares and Pauly, 2019), priors for MSY obtained from maximum catch and for k from $k_{prior} = 4\ MSY_{prior} / r_{prior}$, a multivariate lognormal (MVLN) prior accounting for the negative correlation between k and r within a population, an Artificial Neural Network to predict default relative biomass priors (B/k) from catch relative to prior MSY, based on traits of catch patterns derived from 400 test stocks. The resulting new version is named CMSY++.

Froese et al. (2017; see also Froese et al. 2018, 2019). The CMSY++ code is available from https://oceanrep.geomar.de/53324/ and https://github.com/SISTA16/cmsyPlusPlus.

The CMSY package (Froese et al., 2017) employs two methods – the first (named CMSY, same as the overall tool) uses catch and prior information with a Monte Carlo approach to calculate fisheries reference points, and the second (Bayesian-Schaefer model, BSM) includes relative biomass information to conduct Bayesian state-space simulations of a traditional surplus production model. As the BSM approach uses more information, it is usually able to produce narrower estimates of population biomass trends. In general, both methods produce similar estimates to those of more data-intensive assessments (Martell and Froese, 2013; Froese et al., 2017).

The underlying principles of fisheries management are based on compensatory responses of exploited populations to fishing (Hilborn and Walters 1992). The CMSY approach uses Schaefer's mathematical description and explanation of fish population dynamics (1954; 1957) known as 'surplus-production' modelling. The approach assumes there is a specific carrying capacity for every population in any ecosystem (*k* or unfished biomass B_0), and if this population is reduced due to an external event (e.g., fishing), the population will tend to grow back towards its carrying capacity. A reduction in the stock size - even a small one- will result in more resources (e.g., food items, habitat) for those who remain in the population, mostly resulting in increased juvenile survival rates (Hilborn and Walters 1992). Thus, limiting fishing pressure will allow exploited populations to grow back to their carrying capacity; and keeping populations at certain levels (e.g., *k*/2) can maximize fisheries yields without preventing stock recovery.

Equation (1) describes how the intrinsic rate of population increase (*r*), carrying capacity (*k*), biomass (B_t) and catch (C_t) in a given year can be used to determine biomass (*B*) in the following year (*t+1*). For surplus production and catch, bias-correcting lognormal errors (e^{s_1} and e^{s_2}) are assigned.

$$B_{t+1} = B_t + r\left(1 - \frac{B_t}{k}\right) B_t e^{s_1} - C_t e^{s_2} \quad \ldots 1)$$

When a stock size is severely depleted, a modified Equation (2) is used to account for depensation - the decreased recruitment for a small stock size (Myers et al., 1995; Maroto and Moran, 2014; Perälä and Kuparinen, 2017; Neuenhoff et al., 2019).

$$B_{t+1} = B_t + \left(\frac{4rB_t}{k}\right)\left(1 - \frac{B_t}{k}\right) B_t e^{s_1} - C_t e^{s_2} | \frac{B_t}{k} < 0.25 \quad \ldots 2)$$

This theoretical framework allows the CMSY method to predict biomass trajectories that correspond to biomass reductions due to fishing, carrying capacity (*k*), and intrinsic population growth rate (*r*). Prior densities with central values are calculated using uniform ranges of *r* and *k* (Froese et al., 2017). The most probable 'viable' pair of *r* and *k* is selected generally favouring the assumption of a faster growing, yet smaller population. For an *r*-*k* pair to remain viable, it must not produce a population trajectory that goes extinct.

Both approaches provide estimates of maximum sustainable yield (MSY) as MSY = $r \cdot k/4$, maximum sustainable fishing mortality as $F_{MSY} = r/2$ and minimum biomass that can produce MSY as $B_{MSY} = k/2$ and their respective confidence limits. As well, predictions of relative biomass (B_t / B_{MSY}) and exploitation rate (F_t / F_{MSY}) are generated.

When an abundance index is known (using data sources such as catch-per-unit-of-effort, stock size index, acoustic or trawl survey trends for example), the BSM tool is implemented and an additional parameter (i.e. catchability or *q*) is estimated to convert the abundance index into biomass and each tentative biomass trajectory is compared with the available relative biomass trend. Consequently, the confidence intervals around the best estimates of *r* and *k* and along the biomass trajectory are usually narrower with the inclusion of abundance information.

Selecting stocks suitable for CMSY++ analysis

The health status of a population was determined according to the Precautionary Approach health status zones in the most recent report produced by DFO or Regional Fisheries Management Organization (RFMO). There were 94 stocks identified as having 'uncertain' status between July 2020 and July 2021 (Oceana Canada, 2021). Of these, seven were excluded due to discard-dominated catches, as discards tend to be less documented than landed catches and may represent unreliable time series (Palomares et al., 2018). An additional five multispecies stocks were excluded since species-level catches or information to reliably disaggregate total catches were both unavailable. For example, the Pacific krill fishery harvests multiple species such as *Euphausia pacifica*, *Thysanoessa spinifera*, *Thysanoessa inspinata*, *Thysanoessa longipes* and *Thysanoessa rashii* among others which are not disaggregated due to the size of the organisms and nature of the fishery. Three stocks did not have any documents available and catches from external databases were not disaggregated to the species-level or representative of the stock area. One fishery (Northern abalone) has been closed since 1990 and was excluded from the analysis since recent catches are needed to estimate current biomass. Overall, 15 stocks were excluded since they did not meet the criteria for CMSY assessment eligibility (Table A1).

There were four stocks consisting of multiple species or multiple management units that were split into the appropriate species-level and unit for management purposes and defined as new split stocks, resulting in an additional five eligible 'uncertain' status stocks (Table 1).

Table 1. New stock names from the original Oceana stock ID (Oceana Canada, 2021) for CMSY population stock assessment

Old Stock Name	New Split Stock Name	Name
ATHERR_4S	ATHERR_4Sfall	Herring 4S (Fall spawners)
ATHERR_4S	ATHERR_4Sspring	Herring 4S (Spring spawners)
LOB_QCNSAI_LFA15-18_17	LOB_QCNSAI_LFA15-16	Quebec north shore and Anticosti Island (LFA 15-16)
LOB_QCNSAI_LFA15-18_17	LOB_QCNSAI_LFA17	Quebec north shore and Anticosti Island (LFA 17)
LOB_QCNSAI_LFA15-18_17	LOB_QCNSAI_LFA18	Quebec north shore and Anticosti Island (LFA 18)
INCLA_DE; INCLA_SCVI	BUTCLA_BC	Butter clam (South Coast- Vancouver Island)
INCLA_DE; INCLA_SCVI	LITCLA_BC	Littleneck clam (South Coast- Vancouver Island)
INCLA_DE; INCLA_SCVI	MANCLA_BC	Manila clam (South Coast- Vancouver Island)
INCLA_DE; INCLA_SCVI	RAZCLA_BC	Razor clam (South Coast- Vancouver Island)

Overall, 84 (94-15+5) stocks out of the total 99 'uncertain' stocks were eligible for CMSY analysis (Table A1).

Catch input file - Catch and relative biomass time series

For each stock, the most recent publication was identified through the Canadian Science Advisory Secretariat (CSAS) database. Catch time series were extracted from figures in official reports using the freely available web-tool WebPlotDigitizer[3] and from tables using the Tabula[4] application. For Atlantic stocks, the Northwest Atlantic Fisheries Organization (NAFO) Annual Fisheries Statistics Databases[5] were searched for the corresponding stock area to update catch times series to recent years (2016-2021). In the few cases where catches were not available in either of these databases, reconstructed catches (Pauly, 1998; Zeller and Pauly, 2016) were extracted from the *Sea Around Us*[6] in the Marine Ecoregion or Exclusive Economic Zone corresponding to the stock distribution. If there were gaps in the time series due to unpublished data, catches were interpolated in order to have a continuous time series (Zeller and Pauly, 2016).

The longest available time series was chosen to avoid truncating the time series of catches used for stock assessments (Schijns and Pauly, 2021), a commonly used

[3] https://apps.automeris.io/wpd/

[4] https://tabula.technology/

[5] https://www.nafo.int/Data/STATLANT-21A

[6] http://www.seaaroundus.org/data/#/eez

practice in official stock assessments which may lead to over-optimistic conclusions. The longest time series includes 102 years of catches from the Upper North Shore stock of softshell clam in Quebec coastal waters (Table A1). Short time series were associated with exploratory or emerging fisheries, mainly for invertebrates like sea cucumber, sea urchin and whelk. The average catch time series was 45 years in length. All sources and calculations were documented in the catch input file (see Supplementary Materials).

Where available, time series of relative biomass (catch-per-unit-of-effort, abundance, biomass index, spawning stock biomass, etc.) were extracted from official reports in order to implement the Bayesian Schaefer Model (BSM) in addition to the CMSY approach (Froese et al., 2017). Relative biomass time series were sourced from fishery-independent surveys whenever possible to avoid biases attributed to changing gear and technologies that increase a fleet's fishing power and intensity over a short period of time (Palomares and Pauly, 2019).

For stocks with multiple time series of relative biomass, the average trend was obtained using the state-space harmonization process described in Winker et al. (2019). Standardized relative biomass time series and sources were inputted into the catch input file and corresponding references were stored in a database with PDFs of the official reports. Overall, 72 stocks had relative biomass information, 29 of which had multiple time series available and were harmonized into standardized time series (see Supplementary Materials). Table A2 displays key parameter values and model outputs for all stocks with available abundance information, for which both methods (CMSY++ and BSM) were performed.

ID input file – Stock description, biological parameters and biomass windows

The majority (n=49) of stocks had estimates for resilience and intrinsic rate of population growth (*r*) available from FishBase[7] for finfishes or SeaLifeBase[8] for invertebrates. In selected cases (n=4) with priors available from FishBase, *r*-ranges were set based on published literature (Hutchings et al., 2012b). In cases where resilience was available, but the *r*-range was unavailable (n=15), the *r*-range was assumed following Froese et al. (2017; see Table 2). In cases where neither prior was available (n=16, all invertebrates), medium resilience was assumed as default. Sensitivity analyses were performed for the 16 stocks to see how key parameter values and model outputs varied when using low, medium and high resilience (Table A3).

[7] https://www.fishbase.se/

[8] https://www.sealifebase.ca/

Table 2. Prior ranges for parameter *r*, based on classification of resilience following Froese et al. (2017).

Resilience	Prior *r*-range
High	0.6 – 1.5
Medium	0.2 – 0.8
Low	0.05 – 0.5
Very low	0.015 – 0.1

Independent prior knowledge based on anecdotal evidence or figures in official reports on the reduction of biomass by fishing from carrying capacity at the start, intermediate and/or end of the time series was translated into broad ranges according to Froese et al. (2017; see Table 3). Where a rough estimate of *B/k* was available in the literature, a confidence interval of +/-0.2 was used. For example, a fractional range for an estimate of 0.4, would translate to a biomass window of 0.2 to 0.6 for terms equivalent to medium depletion. Otherwise, for cases where such information is not available CMSY++ provides default biomass priors which are proposed by an Artificial Neural Network (Fritsch et al. 2019) routine to predict default relative biomass priors (*B/k*) from catch relative to prior MSY, based on traits of catch patterns derived from 400 test stocks (Froese et al., in review).

Table 3. Independent knowledge on the reduction of biomass (*B)* by fishing or from carrying capacity (*k*) following ranges based on Froese et al. (2017).

Depletion level	Prior *B/k* range
Very strong depletion	0.01 – 0.2
Strong depletion	0.01 – 0.4
Medium depletion	0.2 – 0.6
Low depletion	0.4 – 0.8
Very low depletion or nearly unexploited	0.75 – 1.0

For the first run of the analysis, all biomass windows were set=NA in order to get a baseline of CMSY results without independent knowledge incorporated. A second run incorporated biomass windows set based on estimates available in the official literature and manual adjustments to improve the fit of biomass trends to priors.

Expert consultation process

The resulting initial assessments were subject for review by species population experts knowledgeable in the history and status of their regional stocks. Results from the stock assessments were prepared with questions to experts to provide commentary and additional information when available.

The project was introduced as part of Oceana Canada’s Fishery Audit briefings in October and November 2021. Fisheries and Oceans Canada assembled a list of regional and species experts who were contacted for this review process. The

Regional Directors of Science for all DFO offices were contacted to engage with stock leads familiar with regional management units. A total of 11 experts were contacted and engaged with reviewing 23 stock assessments.

The stock assessment review process involved asking the expert a series of questions (listed below) based on the output figure for the specific stock.

Questions to expert:

1) Do you have any suggestions/ concerns / additional considerations for the CPUE time series;
2) Do you have any suggestions/ concerns / additional considerations for the catch time series? Please indicate if there are (and where we would be able to find) data on unpublished catch time series available for the stock/species assessed in order to expand the current time series and/or update to recent years;
3) Do you have any suggestions/ concerns / additional considerations for the biomass trend? We are especially interested in receiving input on the final year relative biomass range.

As well, any active work to develop reference points was included in the comments.

Final assessments

The comments collected in the review process were integrated into the input files and the assessments were rerun. The results were used to assign preliminary stock status according to the Precautionary Approach (Figure 1). As well, a reliability score was assigned to each stock assessment based on the type of assessment model and sources of prior information (Table 4). The reliability score is based on a scale of 1 – 4: 1 being the least reliable, 4 being the most reliable (Palomares et al., 2021). The goal of the ranking is to identify further data limitations and areas for future research, especially for stocks that may be in critical condition but are lacking relative biomass information and expert input. The final stock assessment database includes the priors used in the CMSY++ input files (ID and Catch files) and the results of the CMSY++ model (Output file). The files can accommodate new information as it becomes available in order to provide recent and updated assessments.

Table 4. Reliability score assignment based on assessment type (BSM or CMSY+) and end biomass source (expert or literature or manual setting or NA). All sources are documented in the input file and reference database in Supplementary Materials,

Reliability	Assessment type	End biomass source
4	BSM	Expert/Literature

3	BSM	Manual setting/NA
2	CMSY++	Expert/Literature
1	CMSY++	Manual setting/NA

Results

Preliminary stock status estimates

Our analysis reveals that the 99 stocks previously deemed 'uncertain' can be categorized according to the Sustainable Fisheries Framework into 30% (n=30) healthy, 32% (n=32) cautious, 22% (n=22) critical and 15% (n=15) 'uncertain'. The results indicated that in recent years, 37% (n=31) of the assessed populations (n=84) may be fished at rates higher than what is required to achieve MSY ($F > F_{MSY}$). Indicators and fisheries reference points for biomass and fishing mortality are available for all assessed stocks including recent estimates, upper and limit reference points (Table A4).

The inclusion of these newly categorized stocks in Oceana Canada's latest Fishery Audit results suggests that overall, 40% (n=94) of the nation's commercial fisheries may be considered healthy (Figure 2). The rest of the available stocks are in various levels of depletion, with around 25% (n=58) in the critically depleted category and 29% (n=67) in the cautious zone[9]. Of the 99 previously 'uncertain' stocks identified in the 2021 Fishery Audit, 76 are index stocks and only 5% of these stocks remain uncertain with the inclusion of CMSY++ assessments (Figure 3). Around 33% of the 2021 Fishery Audit index 'uncertain stocks' have had stock statuses reassigned, resulting in an increase from the 2021 Audit findings of 11% healthy stocks, 13% cautious stocks and 8% more critical stocks. (Figure 3). Overall, regardless of the new assessments coming from index-only or the complete Fishery Audit stock list, the proportions across stocks status assignments are similar (see Figure 1 and 2).

[9] See Fisheries rebuilding success indicators 2021: Oceana Canada's Fishery Audit stock list is closer to representing all marine fish and invertebrate stocks that are managed within Canada and are subject to targeted or incidental commercial fishing pressure than the SSF, which only includes major commercial stocks, but several minor stocks are still missing from the list. There is no comprehensive list of all commercial fish stocks subject to federal management in Canada. In Oceana Canada's subsequent Fishery Audits, efforts were made to continue to strive towards a comprehensive stock list by adding to the dataset any further stocks found in newly available information from departmental science reports, departmental work plans, or new additions to the SSF. Of the Uncertain stocks identified in the 2021 Fishery Audit, 23 are not index stocks. Therefore, totals were calculated using the complete stock list for all years: 2017 (n=194), 2018 (n=214), 2019 (n=222), 2020 (n=226), 2021 (n=229), Updated CMSY status (n=234).

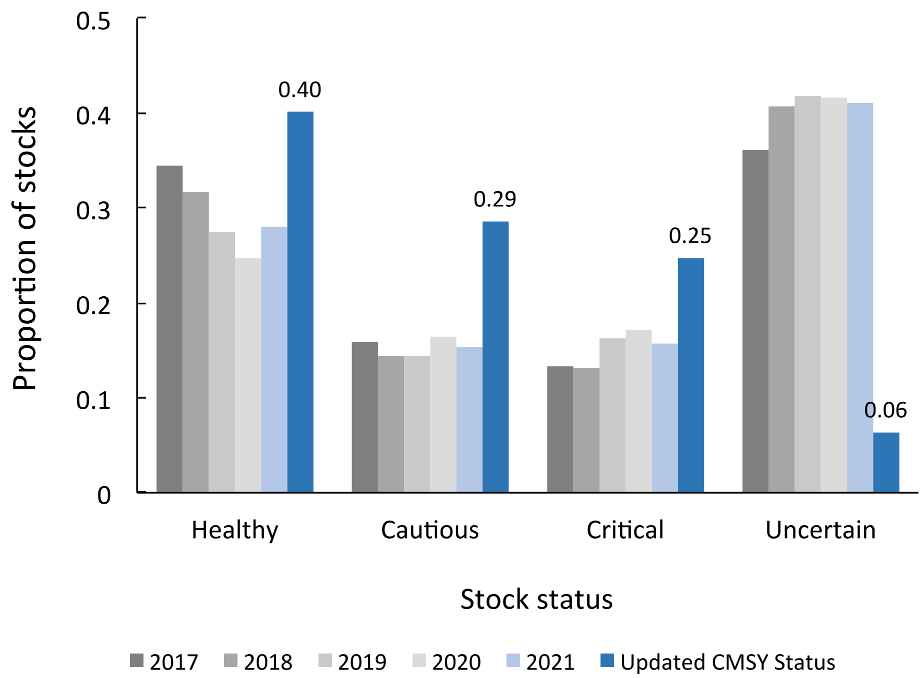

Figure 2. The proportion of stocks with a health based on the Precautionary Approach according to the results of CMSY++ stock assessments (Updated CMSY Status) and the past five Oceana Canada Fishery Audits (2017-2021). Of the Uncertain stocks identified in the 2021 Fishery Audit, 23 are not index stocks. Therefore, proportions were calculated using the complete stock list for datasets: 2017 (n=194), 2018 (n=214), 2019 (n=222), 2020 (n=226), 2021 (n=229), Updated CMSY status (n=234).

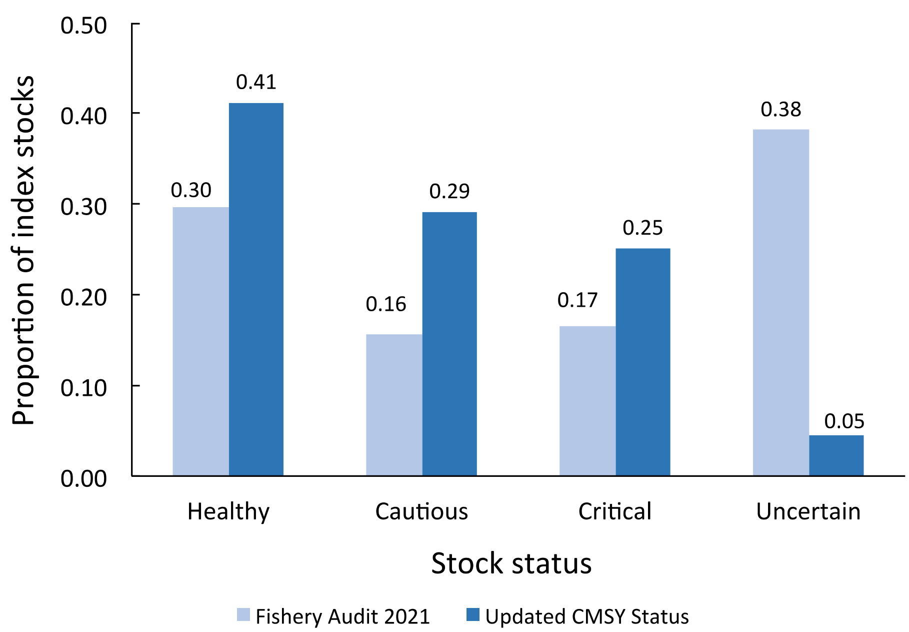

Figure 3. The proportion of stocks with a health based on the Precautionary Approach according to the results of CMSY++ stock assessments (Updated CMSY Status) and the 2021 Oceana Canada Fishery Audit for index stocks. The index stock list includes 194 stocks, and with the addition of the split stocks identified in Table 1, the total stock list is 199 stocks to compare across

datasets. Of the previously 'uncertain' stocks identified in the 2021 Fishery Audit, 76 are index stocks.

All except 12 stock assessments had improved biomass trajectories as a result of informative Bayesian priors, thus narrowing the uncertainties of this approach with information from experts and literature. Model outputs produced by the CMSY++ and BSM methods were compared to see whether there was consistency in the findings regardless of the stock assessment methods (see Table A2). In 63% (n=44) of the assessments, the CMSY++ method tended to underestimate stock status in comparison to BSM estimates. In cases where medium resilience was assumed (n=16), sensitivity analyses revealed that in two cases, setting the resilience parameter to low or high resilience resulted in a stock status change (Table A3).

Of the newly assessed populations, the majority were found in Newfoundland and Labrador (n=29), Quebec (n=23), Pacific (n=19) and Maritimes (n=8) regions (Table 5). Most of the stocks were in the healthy zone in Quebec, while most of the stocks in Newfoundland and Labrador and the Pacific region were in the cautious zone. Regarding taxonomic groups, nearly half of the stocks (n=41) were invertebrates. The next largest group was groundfish (n=14) followed by sharks and skates (n=12) (Table 5).

Table 5. Summary of stock assessment categories and number of stocks within each stock status zones

			Stock Status			
			Healthy	Cautious	Critical	Total
Assessment type		BSM	26	26	18	70
		CMSY++	4	6	4	14
Reliability Score	Data-poor	1	2	6	4	12
		2	2	-	-	2
	Data-rich	3	9	8	6	23
		4	17	18	12	47
Is overfishing occurring? ($F > F_{MSY}$)		No	24	20	9	53
		Yes	6	12	13	31
Region		Arctic	-	1	-	1
		Gulf	1	1	-	2
		Maritimes	2	3	3	8
		National Capital	2	-	-	2
		Newfoundland and Labrador	6	13	10	29
		Pacific	6	8	5	19
		Quebec	13	6	4	23
Taxonomic Group		Flatfish	2	2	1	5
		Forage fish	2	3	3	8
		Groundfish	3	5	6	14

	Invertebrate	18	13	10	41
	Large pelagic	1	-	-	1
	Rockfish and redfish	-	3	-	3
	Sharks and skates	4	6	2	12

Discussion

Insights on the current state of Canada's fisheries

A key finding of the report is that it is possible to perform assessments for nearly all the marine fish and invertebrate populations exploited by fisheries throughout Canada. Thus, we now have a better understanding of the state of Canada's marine fisheries. Over half (125 of 234 total stocks in the cautious and critical zone) of Canadian commercial fish stocks have been overfished and need to be rebuilt back to healthy levels.

These findings are consistent with previous studies that have demonstrated widespread overfishing in Canadian coastal waters (Hutter, 2015; Pauly et al., 2001; Schijns, 2020) and the need to implement rebuilding measures (Archibald and Rangeley, 2020; CESD, 2016; Hutchings et al., 2020). Rebuilding to healthy levels is an essential investment in the future resilience of Canada's costal communities and oceans. According to studies by Sumaila and Teh (2019; 2020), rebuilding scenarios could yield economic gains that are more than 11 times greater than maintaining current catches on depleted Canadian stocks. Other studies provide rebuilding scenarios for depleted stocks and conclude that halting harvesting ensures rapid recovery and reduces the number of highly profitable stocks facing depletion (Costello et al., 2012; Froese et al., 2018). Furthermore, rebuilding fosters biodiversity, habitat restoration, socio-cultural systems and food security (Sumaila et al., 2012).

In the short-term, however, management must take steps to ensure that fishers are financially supported, and the rights of Indigenous peoples are upheld. While fishery closures are an effective method for recovering depleted stocks, they have repercussions for the fishing community. Oftentimes, social costs exceed fishers' incomes and impact fishers' wellbeing in multiple ways (Weeratunge et al., 2014). Social dimensions such as community history, culture, sense of belonging and way of life contribute to a 'satisfaction bonus' in the fisheries occupation, which cannot be measured solely on economic grounds (McGoodwin, 2001). Therefore, fishers are often resistant to alternative livelihoods unless there are nonmonetary benefits equal or greater than the social benefits gained from fishing (Pollnac and Poggie, 2008). Thus, halting harvesting should only be seriously considered for stocks in the critical zone. However, for those in the cautious zone, gradual approaches, such as partially reducing harvest rates and/or fishing effort, or implementing bycatch quotas, can be efficient measures. Implementing these strategies successfully has been shown to be effective around the world (Melnychuk et al., 2017; Hilborn et al., 2020). Moreover, management actions considered suitable and legitimate by stakeholders are more likely to be respected (Bennett and Satterfield, 2018). Therefore, processes that encourage cooperation, collaboration, and capacity development to support shared decision-making and co-produce knowledge helps foster the trust and transparency necessary to support small-scale and indigenous communities.

According to the analyses, in this report, an additional 22 stocks may be critically depleted, bringing the total number of critical stocks in Canada to 58. As of 2021, only seven stocks in the critical zone have rebuilding plans in place, and the quality of those plans has faced criticism (Levesque et al., 2021). With only two plans (Northern cod and Atlantic mackerel) released in the last year, DFO has committed to developing and implementing eight more rebuilding plans by the end of March 2022 (Oceana Canada, 2021), which were asserted to be unlikely to be completed on time (Archibald et al., 2020), and indeed this is the case as of April 2022. The results of delayed management action can include diminished yields, longer rebuilding periods and increased likelihood of stock collapses (Shertzer and Prager, 2007). A more streamlined process and greater investment in developing strong rebuilding plans to address possible new critical stocks could be prioritized in future work plans[10]. Rebuilding regulations that incorporate clear definitions, targets and timelines in a transparent and timely process will provide the best chances for stock recovery (Elmslie 2019; 2021). The newly released rebuilding regulations now provide the legal requirement for plans to include both targets and timelines (*Canada Gazette*, Part II, 2022). There are currently thirty stocks listed in the regulations, 16 of which have a critical status and now require a rebuilding plan to be developed within a minimum of 24 months. Without further research to define stock status for 'data-poor' populations, stocks that may be considered critical will remain uncertain and the provisions under the *Fisheries Act* rebuilding regulations will not apply, risking further decline towards collapse instead of being afforded the chance to flourish.

Another indicator of an unsustainable ecosystem is described by "fishing down the marine food web" – when long-lived, high trophic level fish become depleted, fisheries shift towards short-lived, lower trophic level species, as measured by the mean trophic level of catch over time. This practise has been shown on a global scale (Pauly et al., 1998; Pauly and Palomares, 2005) as well as on the East and West coasts of Canada (Pauly et al., 2001). A further signal of fishing down the marine food web is seen when looking at the number of stocks and their status in taxonomic groups over time. Over five years of Oceana Canada's Fishery Audits,

---

[10] https://www.dfo-mpo.gc.ca/about-notre-sujet/publications/work-plan-travail/index-eng.html

there are fewer healthy forage fish stocks, and the invertebrate group has grown from one critical stock to twelve stocks. With the inclusion of these newly assessed populations, there may be an additional ten invertebrate stocks with critically depleted biomass and nine indicating a cautious state. "Fishing down" results in simplified food webs (Pauly et al., 2001), concentrating fishing on a few populations, as seen in Canada where the majority of commercial landed value comes from four invertebrate taxa groups[11]. Fostering resilient marine invertebrate populations is integral to counteract the "fishing down" problem, which is especially urgent in the face of multiple stressors from ocean warming, acidification and pollution (Byrne and Przeslawski, 2013; McIntyre et al. 2021).

Advantages

Utilizing the CMSY++ tool offers the possibility to estimate the health status for data-limited stocks that may otherwise continue to be fished and managed without scientifically informed reference points. There was sufficient data available for 84 stocks, previously considered data-deficient and 'uncertain' status, to estimate biomass trends and produce preliminary reference points in accordance with the Precautionary Approach and recent commitments in the updated Fisheries Act (Lafrance and Nguyen, 2018).

This assessment method also has the advantage of incorporating fragmented abundance information and 'expert' knowledge on biomass depletion at any point of time (Froese et al., 2017). While not a requirement for an accurate analysis, conducting reassessments and incorporating additional knowledge as it becomes available improves the model and results. The bulk of stocks (83%, n=70) had biomass information sourced from government scientists and scientific reports; therefore, te analyses were considered data-rich compared to those that were informed solely from catch records.

Additionally, the method includes an optional technological 'creep' factor to account for the slow increase in the effectiveness of fishing gear due to newly introduced technologies that enhance a fleet's fishing power and intensity. The 'creep' factor can be applied to adjust for the change in catchability, usually around 2-4% per year (Palomares and Pauly, 2019). The 'creep' factor was not applied in this analysis since all the biomass indices were available from fishery-independent surveys or in standardized form. However, this feature further highlights capabilities that can be used in assessments beyond the ones displayed in this report.

---

[11] In 2020, DFO reports total landed value of $2,478,539, 69% of which comes from clams/quahog, lobster, shrimp and queen crab. Available at: https://www.dfo-mpo.gc.ca/stats/commercial/land-debarq/sea-maritimes/s2020pv-eng.htm

Limitations

Sources of bias

In all cases, the quality of an analysis is dependent on the quality of the data used. Considering that CMSY methods are largely based on reported commercial catch time series, the uncertainty associated with unreported components should be taken into consideration when interpreting the assessment outcomes. Reported catches may not include components primarily absent or underreported even though fishing is occurring. For example, the absence of small-scale landings, discards, foreign activity and illegal, unregulated and unreported (IUU) catches[12] (Ainsworth and Pitcher, 2005; Booth and Watts, 2007; Divovich et al., 2015; Teh et al., 2015; Zeller et al., 2011) may lead to underestimating fishing mortality, current status and affect policy decisions. Catch reconstruction methods have been largely employed across Canada (Schijns, 2020) and globally to generate more comprehensive scientific baselines (Pauly and Zeller, 2016; Palomares et al., 2021).

As well, stock dynamics may not be reflected in catch time series when harvest limits are influenced by unrelated factors such as market-driven demand, newly protected areas or species, changing carrying capacity or distribution due to climate change induced warming waters and regime shifts. For example, bivalve fisheries across the British Columbia coast are prohibited until biotoxin levels are tested and meet required standards for opening (Bates et al., 2020). In the past ten years, testing has become increasingly restrictive as a result of the increased prevalence of Paralytic Shellfish Poisoning (PSP) among intertidal bivalves (McIntyre et al. 2021), thereby limiting opportunities to harvest. In the Atlantic, DFO claims that recent warming conditions may lead to a reduction in the optimal thermal habitat for snow crab, affecting its distribution. Such environmental changes can also affect population life history and growth, so it can be expected that these changes will impact the *r* and *k* parameter values of surplus production models[13] (Walters 1987; Hilborn and Walters, 1992).

---

[12] Many recreational and bait fisheries have little to no monitoring or reporting requirements (Archibald et al., 2021)

[13] DFO notes that Crab Management Areas (CMAs) are generally too small to constitute biologically meaningful units. The genetic stock spans all Atlantic Canada (Puebla et al., 2008) and their distribution, productivity, and growth rates vary according to changes in water temperature (DFO 2020). Therefore, an additional assessment was conducted based on combining management unit's catch and relative abundance data into a single stock to compare parameters and estimates relative to reference points. The aggregated assessment estimates the stock to be in the cautious zone, with biomass showing a declining trend and overfishing occurring (Table A5). The single stock estimate of B/B_{MSY} is within the 95% confidence limits for all units except for 12B. On March 25, 2022, DFO announced a closure of the commercial snow crab fishery in Area 12B to allow the recovery of this stock and develop a rebuilding plan (see https://www.qc.dfo-mpo.gc.ca/en/announcement-moratorium-commercial-snow-crab-fishing-area-12bgaspe-area-notice-fishers), indicating a critical condition (which is identified by the unit-level

Despite these challenges to managing bivalves, management measures that limit harvests can be used to inform the prior relative biomass windows for certain time periods. For example, if a decrease in catch is attributed to a management measure based on toxin levels, then the biomass range for that year can be set at the level prior to implementation of the management measure. In such instances, abundance information or expert knowledge would also help specify the model. Unfortunately, this information was not readily available for five bivalve stocks in this study, and their results should be interpreted with uncertainty, as reflected by their low reliability score.

It is also important to stress that single-species stock assessment models do not take trophic interactions into account. Species targeted by fishers are also prey of other fishes (potentially other targeted stocks), marine mammals and seabirds. Harvesting all targeted species within an ecosystem at F_{MSY} or attempting to maintain all stocks at or above B_{MSY}, is unlikely to be successful, and such policies are likely to negatively impact ecosystem structure and function (including the loss of top predators) (Walters et al., 2005). In situations where predators and prey are simultaneously fished at F_{MSY}, there will always be 'winners' and 'losers'. Therefore, fishery ecosystem plans (Levin et al., 2018) that use holistic approaches to assess ecosystem overfishing (Coll et al., 2008; Link and Watson, 2019) should be developed whenever possible and used to inform management decisions including rebuilding.

Finally, it is important to recall that surplus production models, which are the foundational models used in CMSY++, assume populations have a single unit of biomass with uniform growth and mortality rates (ie. no age structure). While CMSY++ has been proven to be a valuable tool for data-limited scenarios despite this, management actions based on surplus production assessments such as CMSY++ should focus on estimates of predicted biomass rather than estimated fishing mortality, which may be underestimated for fisheries with several age classes making up the catch.

Excluded stocks and low reliability

There were 15 stocks that were not eligible for analysis due to their catches coming from mainly non-directed sources (i.e. discards, bycatch), aggregated taxonomic groups, closed fisheries, and short time series or lack of documents. The findings in this report and other published materials (Liang et al., 2020; Zhang et al., 2020; Zhou et al., 2018) have illustrated the value of using only catches to evaluate exploited populations. For that reason, improving catch monitoring

---

assessment but not by the single stock assessment). As well, the single stock estimate of F/F_{MSY} is within the 95% confidence limits for all stocks, with all but one unit (12A) experiencing overfishing.

(Archibald et al., 2021) and documenting catches for at least 20 years may be able to provide insights on the current state of these fisheries.

As well, there were twelve stocks with low reliability (=1) scores, four of which indicated critical biomass trends and six in the cautious zone. When both BSM and CMSY++ were applied, CMSY++ tended to underestimate stock status. This highlights the need for developing biomass indices from fishery-dependent or independent surveys and traditional knowledge for the stocks that lack them (Table A2). For all stock assessments, including data-limited ones, it is best practice to be transparent about assumptions that could alter results, especially when lacking information to support a choice of input parameter value over another (Punt et al., 2016). Uncertainties regarding input parameters can lead to management advice that is either too lax (i.e., fishing pressure is allowed to remain higher than it should, negatively affecting the stocks and the ecosystems where they are found) or too punitive (i.e., fishing pressure is restricted beyond what is necessary, causing losses in fishers' revenue as well as across the value chains that depend on their catches). According to sensitivity analyses presented in Table A3, assuming different resilience levels for 16 stocks results in variable stock status in the final year for two stocks. This illustrates the need to do more research about the life histories of these particular resources.

The Fishery Monitoring Policy (DFO, 2019) has the potential to address these data gaps and improve collection methods. Monitoring via logbooks, dockside and at-sea methods has improved over the past five years (Oceana Canada, 2021), yet the policy has not been fully implemented across all Canadian fisheries (DFO, 2021). By prioritizing the implementation of this policy, it is possible to produce robust and reliable assessments, thus meeting other national objectives to achieve sustainable fishing. Even though this approach has its limitations, it is useful for highlighting stocks in need of urgent attention and for providing starting points for improved management for these 84 stocks.

Conclusion

While the Canadian government takes steps toward implementing the Precautionary Approach in the Sustainable Fisheries Framework (DFO, 2009), this research reveals new information about the health of Canada's fisheries and applies versatile tools that can be used to advance deliverables that DFO commits to each year. By upholding national and international commitments, Canada has the chance to reach it's potential as a global leader in fisheries management and ocean conservation.

Effective and precautionary management of fish populations depends on knowing the population status - otherwise, it is easy to overfish and drive populations to a more vulnerable state. The state of the world's oceans is projected to worsen according to the Intergovernmental Panel on Climate Change (IPCC) Special

Report (Bindoff et al., 2019). Ocean acidification, marine heat waves and increasing ocean temperatures are likely to have major consequences on fisheries and the marine economy (Sumaila et al., 2011), as they have ramifications on species distribution, ecosystem productivity, and biology (Bindoff et al., 2019).

By using the best available data to assign a health status to more fish stocks, Canada can unlock needed intervention through policy and management commitments. In doing so, Canada can manage fisheries in ways that prioritize their long-term health, abundance that is essential for fulfilling Food, Social, and Ceremonial purposes as well as commercial and recreational.

Supplementary Materials

1. Data S1. Catch input file (Oceana_Catch.csv).
2. Data S2. ID input file (Oceana_ID.csv).
3. Data S3. Output file (Oceana_Out.csv)
4. Data S4. Reference database (Oceana_Relbio_References.xlsx)

References

Ainsworth, C.H. & Pitcher, T.J. (2005). Estimating illegal, unreported and unregulated catch in British Columbia's marine fisheries. Fish. Res. 75, 40-55. doi: 10.1016/j.fishres.2005.05.003

Anderson, S.C., Lotze, H.K. & Shackell, N.L. (2008). Evaluating the knowledge base for expanding low-trophic-level fisheries in Atlantic Canada. Can. J. Fish. Aquat. Sci. 65, 2553-2571.

Archibald, D.W., McIver, R. & Rangeley, R. (2020). Canada's Progress towards Completing Commitments to Implement the Sustainable Fisheries Framework. In: Fishery Audit: 2020. https://oceana.ca/sites/default/files/canadas_progress_towards_completing_commitments_2020_final.pdf

Archibald, D.W., Whyte, J. & Rangeley, R. (2021). Counting Fish: Why Fisheries Monitoring Matters. Oceana Canada. https://oceana.ca/en/publications/reports/ counting-fish-why-fisheries-monitoring-matters

Bates, S.S., Beach, D.G., Comeau, L.A., Haigh, N., Lewis, N.I., Locke, A., Martin, J.L., McCarron, P., McKenzie, C.H., Michel, C., Miles, C.O., Poulin, M., Quilliam, M.A., Rourke, W.A., Scarratt, M.G., Starr, M. & Wells, T. (2020). Marine harmful algal blooms and phycotoxins of concern to Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3384: x + 322 p.

Bennett, N. J. & Satterfield, T. (2018) Environmental governance: A practical framework to guide design, evaluation, and analysis, Conservation Letters. 11 (2018) e12600-13. doi: 10.1111/conl.12600.

Bindoff, N.L., Cheung, W.W.L., Kairo, J.G., Arístegui, J., Guinder, V.A., Hallberg, R., Hilmi, N., Jiao, N., Karim, M.S., Levin, L., O'Donoghue, S., Purca Cuicapusa, S.R., Rinkevich, B., Suga, T., Tagliabue, A. & Williamson, P. (2019). Changing Ocean, Marine Ecosystems, and Dependent Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate.

Booth, S. & Watts, P. (2007). Canada's Arctic Marine Fish Catches. Zeller, D. and Pauly, D. (Eds.) Reconstruction of marine fisheries catches for key countries and regions (1950-2005), 3-15. Fisheries Centre Research Reports 15(2). University of British Columbia, Vancouver.

Bourne, C., Murphy, H., Adamack, A.T., & Lewis, K. (2021). Assessment of Capelin (Mallotus villosus) in 2J3KL to 2018. DFO Can. Sci. Advis. Sec. Res. Doc. 2021/055. iv + 39 p.

Buren, A.D., Murphy, H.M., Adamack, A.T., Davoren, G.K., Koen-Alonso, M., Montevecchi, W.A., Mowbray, F.K., Pepin, P., Regular, P.M., Robert, D. & Rose, G.A. (2019). The collapse and continued low productivity of a keystone forage fish species. Marine Ecology Progress Series, 616, pp.155-170.

Byrne, M., & Przeslawski, R. (2013). Multistressor impacts of warming and acidification of the ocean on marine invertebrates' life histories. Integrative and comparative biology, 53(4), 582-596. doi: 10.1093/icb/ict049

Canada Gazette, Part II, Volume 156, Number 8. SOR/2022-73 April 4, 2022. Available online https://www.canadagazette.gc.ca/rp-pr/p2/2022/2022-04-13/html/sor-dors73-eng.html)

Castañeda, R.A., Burliuk, C.M.M., Casselman, J.M., Cooke, S.J., Dunmall, K.M., Forbes, L.S., Hasler, C.T., Howland, K.L., Hutchings, J.A., Klein, G.M., Nguyen, V.M., Price, M.H.H., Reid, A.J., Reist, J.D., Reynolds, J.D., Van Nynatten, A. & Mandrak, N.E. (2020). A Brief History of Fisheries in Canada. Fisheries (Bethesda) 45, 303-318.

Coll, M., Libralato, S., Tudela, S., Palomera, I. & Pranovi, F. (2008) Ecosystem Overfishing in the Ocean, PLoS ONE. 3: e3881-10. doi: 10.1371/journal.pone.0003881.

Commissioner of the Environment and Sustainable Development (CESD) (2016). Report 2 — Sustaining Canada's Major Fish Stocks — Fisheries and Oceans Canada. Commissioner of the Environment and Sustainable Development. https://www.oag-bvg.gc.ca/internet/English/parl_cesd_201610_02_e_41672.html

Cooper, A.B. (2006). A guide to fisheries stock assessment: from data to recommendations. University of New Hampshire, Sea Grant College Program.

Costello, C., Kinlan, B. P., Lester, S. E., & Gaines, S. D. (2012). The economic value of rebuilding fisheries. doi: 10.1787/18156797

DFO (2018). Stock Status and Sustainable Harvest Levels for Arctic Char in Ijaruvung Lake, Iqalujjuaq Fiord and Irvine Inlet, Cumberland Sound, Nunavut. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/021.

DFO (2019). Fishery Monitoring Policy. Fisheries and Oceans Canada. https://www.dfompo.gc.ca/reports-rapports/regs/sff-cpd/fishery-monitoring-surveillance-des-pecheseng.htm

DFO (2020) Assessment of the Estuary and Northern Gulf of St. Lawrence (Areas 13 to 17, 12A, 12B, 12C and 16A) Snow Crab Stocks in 2019. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/050.

DFO (2021) Harvest Advice for Pacific Sardine (*Sardinops sagax*) in British Columbia Waters for 2021 DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/034.

DFO (2021). Sustainable Fisheries Framework Work Plan. Fisheries and Oceans Canada. https://www.dfo-mpo.gc.ca/about-notre-sujet/publications/work-plan-travail/2021-2022/wp-pt-eng.html

Divovich, E., Belhabib, D., Zeller, D. & Pauly, D. (2015). Eastern Canada, "a fishery with no clean hands": Marine fisheries catch reconstruction from 1950 to 2010. Fisheries Centre 56, 143-145.

Elmslie, K. (2019). Comments on the DFO Document for Consultation: Proposed Elements of a Regulation to List Major Fish Stocks and to Describe Requirements for Fish Stock Rebuilding Plans. https://oceana.ca/wp-

content/uploads/sites/24/oceana_canada_comments_on_the_dfo_document_for_consultation_0.pdf
Elmslie, K. (2021). Comments on the Proposed Regulations Amending the Fishery (General) Regulations. https://oceana.ca/sites/default/files/final_oceana_canada_comments_on_the_proposed_regulations_amending_the_fishery_general_regulations.pdf
FAO (1995). Code of Conduct for Responsible Fisheries. FAO Doc. 95/20/Rev/1; UN Sales No. E98.V.11 (1998); 1995 WTS 3. http://www.fao.org/fishery/en
Fritsch, S., Guenther, F., and Guenther, M.F. (2019). 'neuralnet' R Package. Training of Neural Networks. Available at https://cran. r-project. org/web/packages/neuralnet/neuralnet. pdf.
Froese, R., Demirel, N., Coro, G. & Winker, H. (2019). A simple user guide for CMSY+ and BSM (CMSY_2019_9f.R). GEOMAR, 1-16.
Froese, R., Demirel, N., Coro, G., Kleisner, K.M. & Winker, H. (2017). Estimating fisheries reference points from catch and resilience. Fish. Fish. 18, 506-526. doi: 10.1111/faf.12190
Froese, R., Winker, H., Coro, G., Demirel, N., Tsikliras, A.C., Dimarchopoulou, D., Scarcella, G., Quaas, M. & Matz-Lück, N. (2018). Status and rebuilding of European fisheries. Marine Policy, 93, 159-170. doi: 10.1016/j.marpol.2018.04.018
Froese, R., Winker, H., Coro, G., Palomares, M. L. D., Tsikliras, A. C., Dimarchopoulou, D., Touloumis, K., Demirel, N., Vianna, G., Scarcella, G., Schijns, R., Liang, C. & Pauly, D. (in review). Catch time series as the basis for fish stock assessments: the CMSY++ method. Frontiers in Marine Science.
Hilborn, R., Amoroso, R.O., Anderson, C.M., Baum, J.K., Branch, T.A., Costello, C., de Moor, C.L., Faraj, A., Hively, D., Jensen, O.P., Kurota, H., Little, L.R., Mace, P., McClanahan, T., Melnychuk, M.C., Minto, C., Osio, G.C., Parma, A.M., Pons, M., Segurado, S., Szuwalski, C.S., Wilson, J.R. & Ye, Y. (2020) Effective fisheries management instrumental in improving fish stock status, PNAS. 117: 2218–2224. doi: 10.1073/pnas.1909726116.
Hilborn, R. & Walters, C. J. (1992) Quantitative fisheries stock assessment: choice, dynamics, and uncertainty. Springer, Boston, MA. doi: 10.1007/978-1-4615-3598-0
Hutchings, J.A. (2014). Renaissance of a caveat: Allee effects in marine fishes. ICES Journal of Marine Science, 71: 2152-2157. doi: 10.1093/icesjms/fst179
Hutchings, J.A. (2015). Thresholds for impaired species recovery. Proceedings of the Royal Society B, 282: 2015 0654. doi: 10.1098/rspb.2015.0654
Hutchings, J.A., Côté, I.M., Dodson, J.J., Fleming, I.A., Jennings, S., Mantua, N.J., Peterman, R.M., Riddell, B.E., Weaver, A.J. & VanderZwaag, D.L. (2012a). Is Canada fulfilling its obligations to sustain marine biodiversity? A summary review, conclusions, and recommendations. Environmental Reviews, 20(4), 353-361.

Hutchings, J.A., Myers, R.A., García, V.B., Lucifora, L.O., & Kuparinen, A. (2012b). Life-history correlates of extinction risk and recovery potential. Ecological Applications, 22(4), 1061-1067. doi: 10.1890/11-1313.1

Hutchings, J.A., Baum, J.K., Fuller, S.D., Laughren, J. & VanderZwaag, D.L. (2020). Sustaining Canadian marine biodiversity: Policy and statutory progress. Facets (Ottawa) 5, 264-288. doi: 10.1139/facets-2020-0006

Hutter, J. (2015). Overfishing in Canada and the United States: A Comparative Study of Policy and Legislation (Master's thesis, University of Calgary). http://hdl.handle.net/1880/51663

Khalfallah, M. (2020). Data-poor fisheries: case studies from the southern Mediterranean and the Arabian Peninsula (Doctoral dissertation). University of British Columbia, Vancouver, Canada.

King, J.R., Surry, A.M., Garcia, S. & Starr, P.J. (2015). Big Skate (*Raja binoculata*) and Longnose Skate (*R. rhina*) stock assessments for British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/070. ix + 329 p.

Lafrance, D. & Nguyen, T. (2018). Bill C-68: An Act to Amend the Fisheries Act and Other Acts in Consequence. Library of Parliament, Ottawa, Canada.

Levangie, P.E., Blanchfield, P.J. & Hutchings, J.A. (2021). The influence of ocean warming on the natural mortality of marine fishes. Environmental Biology of Fishes, 1-15. doi: 10.1007/s10641-021-01161-0

Levesque, B., Archibald, D.W., & Rangeley, R. (2021). The Quality of Recent Rebuilding Plans in Canada. https://oceana.ca/wp-content/uploads/sites/24/The-Quality-of-Recent-Rebuilding-Plans-in-Canada-2021-FINAL.pdf

Levin, P.S., Essington, T.E., Marshall, K.N., Koehn, L.E., Anderson, L.G., Bundy, A., Carothers, C., Coleman, F., Gerber, L.R., Grabowski, J.H. & Houde, E. (2018) Building effective fishery ecosystem plans. Marine Policy. 92: 48–57. doi: 10.1016/j.marpol.2018.01.019

Liang, C., Xian, W., & Pauly, D. (2020). Assessments of 15 exploited fish stocks in Chinese, South Korean and Japanese waters using the CMSY and BSM methods. Frontiers in Marine Science, 7, 623. doi 10.3389/fmars.2020.00623

Link, J.S. & Watson, R.A. (2019) Global ecosystem overfishing: Clear delineation within real limits to production, Sci Adv. 5: eaav0474. doi: 10.1126/sciadv.aav0474.

Maroto, J. M. & Moran, M. (2014). Detecting the presence of depensation in collapsed fisheries: the case of the Northern cod stock. Ecological Economics, 97: 101-109. doi: 10.1016/j.ecolecon.2013.11.006

Martell, S. & Froese, R. (2013). A simple method for estimating MSY from catch and resilience. Fish. Fish. 14, 504-514. doi: 10.1111/j.1467-2979.2012.00485.x

McGoodwin, J. (2001). Understanding the Cultures of Fishing Communities: A Key to Fisheries Management and Food Security. FAO Technical Paper. FAO, Rome. http://www.fao.org/DOCREP/004/Y1290E/y1290e05.htm#bm05.5

McIntyre, L., Miller, A., & Kosatsky, T. (2021). Changing trends in paralytic shellfish poisonings reflect increasing sea surface temperatures and practices of Indigenous and recreational harvesters in British Columbia, Canada. Marine drugs, 19(10), 568.

McIver, R., Rangeley, R. &Archibald, D.W. (2021). Small Fish, Big Influence: The Case for Rebuilding Capelin. Oceana Canada. https://oceana.ca/en/publications/reports/small-fish-big-influence-case-rebuilding-capelin

Melnychuk, M.C., Peterson, E., Elliott, M. & Hilborn, R. (2017) Fisheries management impacts on target species status, Proceedings of the National Academy of Sciences. 114: 178–183. doi: 10.1073/pnas.1609915114.

Mercer, K.B. (2013). Integrated fisheries management of less economically valuable species: a case study of Atlantic hagfish (Myxine glutinosa) in Newfoundland and Labrador, Canada (Doctoral dissertation). Memorial University of Newfoundland, St. John's, Canada.

Myers, R.A., Barrowman, N.J., Hutchings, J.A. & Rosenberg, A.A. (1995). Population dynamics of exploited fish stocks at low population levels. Science 269, 1106-1108. doi: 10.1126/science.269.5227.1106

Neuenhoff, R.D., Swain, D.P., Cox, S.P., McAllister, M.K., Trites, A.W., Walters, C.J. & Hammill, M.O. (2019). Continued decline of a collapsed population of Atlantic cod. Canadian Journal of Fisheries and Aquatic Sciences, 76: 168. doi: 10.1139/cjfas-2017-0190

Oceana Canada (2017). Fishery Audit 2017: Unlocking Canada's Potential For Abundant Oceans. https://oceana.ca/wp-content/uploads/sites/24/fishery_audit_eng.pdf

Oceana Canada (2021). Fishery Audit 2021: Unlocking Our Potential for Abundant Oceans: Canada's Performance from 2017–2021. https://fisheryaudit.ca/FisheryAudit_2021.pdf

Palomares M.L.D., Baxter, S., Bailly, N., Chu, E., Derrick, B., Frias-Donaghey, M., Nöel, S. L., Page, E., Schijns, R., Woroniak, J., Abucay, L., David, E., de Leon, S., Nevado, M., Ortiz, S., Parducho, V.A., Yap, P.S., Ansell, M., Hood, L., Vianna, G., White, R., Zeller, D. & Pauly, D. (2021). Estimating the biomass of commercially exploited fisheries stocks left in the ocean. Fisheries Centre Research Reports 29 (3): 74 pp.

Palomares, M.L.D. & Pauly, D. (2019). On the creeping increase of vessels' fishing power. Ecol. Soc. 24, 31. doi: 10.5751/ES-11136-240331

Palomares, M.L.D., Froese, R., Derrick, B., Nöel, S., Tsui, G., Woroniak, J. & Pauly, D. (2018). A preliminary global assessment of the status of exploited marine fish and invertebrate populations. A report prepared by the Sea Around Us for OCEANA. The University of British Columbia, Vancouver, p. 64.

Parsons, L.S. (1993). Management of Marine Fisheries in Canada. National Research Council of Canada and Department of Fisheries and Oceans. Fishery management, Ottawa, p. 763.

Pauly, D. (1998). Rationale for reconstructing catch time series. EC Fisheries Cooperation Bulletin. 11(2): 4-7 [Disponible en français « Approche raisonné de la reconstruction des séries temporelles de prises », p. 8-10]
Pauly, D. & Palomares, M. (2005). Fishing Down Marine Food Web: It is Far More Pervasive Than We Thought. B. Mar. Sci. 76, 197-212.
Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. & Torres, F. (1998). Fishing down marine food webs. Science 279, 860-863. doi: 10.1126/science.279.5352.860
Pauly, D., Palomares, M.L., Froese, R., Sa-a, P., Vakily, M., Preikshot, D. & Wallace, S. (2001). Fishing down Canadian aquatic food webs. Can. J. Fish. Aquat. Sci. 58, 51-62. doi: 10.1139/f00-193
Pauly, D., Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R., & Zeller, D. (2002). Towards sustainability in world fisheries. Nature 418, 689-695.
Pauly, D., Hilborn, R., & Branch, T.A. (2013). Fisheries: Does catch reflect abundance?. Nature, 494(7437), 303-306. doi: 10.1038/494303a
Pauly, D. & Zeller, D. (2016). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. Nat. Commun. 7, 10244. doi: 10.1038/ncomms10244
Perälä, T. & Kuparinen, A. (2017). Detection of Allee effects in marine fishes: analytical biases generated by data availability and model selection. Proceedings of the Royal Society B: Biological Sciences, 284: 20171284. doi: 10.1098/rspb.2017.1284
Pollnac, R.B. & Poggie, J.J. (2008). Happiness, wellbeing and psychocultural adaptation to the stresses associated with marine fishing. Human Ecology Review 15: 194–200.
Punt, A.E., Butterworth, D.S., de Moor, C.L. Oliveira, J.A.A.D. & Haddon M. (2016) Management strategy evaluation: best practices. Fish and Fisheries. 17: 303–334. doi:10.1111/faf.12104
Ricard, D., Minto, C., Jensen, O.P. & Baum, J.K. (2012). Examining the knowledge base and status of commercially exploited marine species with the RAM Legacy Stock Assessment Database. Fish. Fish. 13, 380-398. doi: 10.1111/j.1467-2979.2011.00435.x
Rice, J. & Rivard, D. (2002). Proceedings of the DFO workshop on implementing the precautionary approach in assessments and advice. Fisheries and Oceans Canada. DFO Can. Sci. Advis. Sec. Proc. 2002/009. https://waves-vagues.dfo-mpo.gc.ca/Library/263770.pdf
Schaefer, M.B. (1954). Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bulletin of the Inter-American Tropical Tuna Commission 1,27-56.
Schaefer, M.B. (1957). A study of the dynamics of populations of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bulletin of the Inter-American Tropical Tuna Commission 11, 247-268.

Schijns, R. (2020). What has Canada caught, and how much is left? Reconstructing and assessing fisheries in three oceans (Masters thesis, University of British Columbia).
Schijns, R., & Pauly, D. (2021). Management implications of shifting baselines in fish stock assessments. Fisheries Management and Ecology. doi: 10.1111/fme.12511
Schijns, R., Froese, R., Hutchings, J.A., & Pauly, D. (2021). Five centuries of cod catches in Eastern Canada. ICES Journal of Marine Science, 78(8), 2675-2683. doi: 10.1093/icesjms/fsab153
Shertzer, K.W., & Prager, M.H. (2007). Delay in fishery management: diminished yield, longer rebuilding, and increased probability of stock collapse. ICES Journal of Marine Science, 64(1), 149-159. doi: 10.1093/icesjms/fsl005
Sumaila, U.R. & Teh, L.S. (2019). Economic and Social Benefits of Fisheries Rebuilding: Six Canadian Case Studies. Oceana Canada. https://oceana.ca/en/publications/reports/economic-and-social-benefits-fisheriesrebuilding
Sumaila, U.R., Cheung, W., Dyck, A., Gueye, K., Huang, L., Lam, V., Pauly, D., Srinivasan, T., Swartz, W. & Watson, R. (2012). Benefits of rebuilding global marine fisheries outweigh costs. PloS one 7, e40542.
Sumaila, U.R., Cheung, W.W., Lam, V.W., Pauly, D. & Herrick, S. (2011). Climate change impacts on the biophysics and economics of world fisheries. Nat. Clim. Change 1, 449-456. doi: 10.1038/nclimate1301
Teh, L.S., & Sumaila, U.R. (2020). Assessing potential economic benefits from rebuilding depleted fish stocks in Canada. Ocean & Coastal Management, 195, 105289. doi: 10.1016/j.ocecoaman.2020.105289
Teh, L.S., Zylich, K. & Zeller, D. (2015). FAO area 18 (Arctic Sea): Catch data reconstruction extension of Zeller et al. (2011) to 2010. Fisheries Centre Research Reports #2015-14. University of British Columbia, Vancouver. p. 5.
Transboundary Resources Assessment Committee (TRAC) (2020). Georges Bank Yellowtail Flounder TRAC Status Report 2020/03.
UN (1995). United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, 4 August 1995, 2167 UNTS 88, 34 ILM 1542 (1995) (entered into force 11 December 2001). Available from http://www.un.org/Depts/los/fish_ stocks_conference/fish_stocks_conference.htm
Walters, C. J. (1987) Nonstationarity of production relationships in exploited populations. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 156-165.
Walters, C.J., Christensen, V., Martell, S.J. & Kitchell, J.F. (2005). Possible ecosystem impacts of applying MSY policies from single-species assessment, ICES Journal of Marine Science. 62 (2005) 558–568. doi: 10.1016/j.icesjms.2004.12.005.

Weeratunge, N., Béné, C., Siriwardane, R., Charles, A., Johnson, D., Allison, E. H., Nayak, P. K. & Badjeck, M.-C. (2014). Small-scale fisheries through the wellbeing lens, Fish and Fisheries. 15: 255–279. doi: 10.1111/faf.12016.
Winker, H., Pacoureau, N. & Sherley, R. (2019). JARA: 'Just Another Red-List Assessment'. BioRxiv, 672899. doi: 10.1101/672899
Winter, A. & Hutchings, J.A. (2020). Impediments to fisheries recovery in Canada: Policy and institutional constraints on developing management practices compliant with the precautionary approach. Mar. Policy 104161. doi: 10.1016/j.marpol.2020.104161
Zeller, D. & Pauly, D. (2016). Marine fisheries catch reconstruction: definitions, sources, methods and challenges, in Anonymous Global Atlas of Marine Fisheries: A Critical Appraisal of Catches and Ecosystem Impacts. Island Press, Washington, DC, p. 12-33.
Zeller, D., Booth, S., Pakhomov, E., Swartz, W. & Pauly, D. (2011). Arctic fisheries catches in Russia, USA, and Canada: baselines for neglected ecosystems. Polar Biol. 34, 955-973. doi: 10.1007/s00300-010-0952-3
Zhang, S., Y. Wang, Y. Wang, C. Liang & W. Xian. (2020). Assessment of 11 exploited fish and invertebrate populations in the Japan Sea using the CMSY and BSM methods. *Frontiers in Marine Science*, 7(525363):1-10. doi:10.3389/fmars.2020.525363
Zhou, S., Punt, A. E., Smith, A. D., Ye, Y., Haddon, M., Dichmont, C. M., & Smith, D. C. (2018). An optimized catch-only assessment method for data poor fisheries. ICES Journal of Marine Science, 75(3), 964-976. doi: 10.1093/icesjms/fsx226

Table A1. Summary of stock information for 99 Canadian marine stocks previously identified as 'uncertain' in the 2021 Fishery Audit, including last year of catches available and length of catch time series used as inputs for the BSM and CMSY++ assessments.

Stock ID	Common name	Scientific name	Stock details	Region	Group	Last year	Time series length (years)
ACRED_23K	Redfish species	Sebastes fasciatus	2+3K Acadian redfish (S. fasciatus)	Newfoundland and Labrador	Rockfish and redfish	2020	59
ARFLO_3CD_5ABCDE	Arrowtooth flounder	Atheresthes stomias	Arrowtooth Flounder - 3CD and 5ABCDE	Pacific	Groundfish	2017	21
ATBTUNA_WATL	Atlantic bluefin tuna	Thunnus thynnus	Bluefin Tuna - Western Atlantic	National Capital Region	Large pelagic	2019	69
ATCOD_2GH	Atlantic cod	Gadus morhua	Atlantic Cod - 2GH	Newfoundland and Labrador	Groundfish	2017	67
ATHAL_4RST	Atlantic halibut	Hippoglossus hippoglossus	Atlantic Halibut - 4RST	Quebec	Flatfish	2020	60
ATHERR_2J3IKLPs_HFA1_to11	Atlantic herring	Clupea harengus	Herring 2J3IKLPs - Herring Fishing Areas 1-11 - Newfoundland east and south coast	Newfoundland and Labrador	Forage fish	2018	52
ATHERR_4Rfall	Atlantic herring	Clupea harengus	Herring 4R (Fall Spawner)	Newfoundland and Labrador	Forage fish	2019	34
ATHERR_4Rspring	Atlantic herring	Clupea harengus	Herring 4R (Spring Spawner)	Newfoundland and Labrador	Forage fish	2019	34
ATHERR_4Sfall	Atlantic herring	Clupea harengus	Herring 4S (Fall Spawner)	Quebec	Forage fish	2018	34
ATHERR_4Sspring	Atlantic herring	Clupea harengus	Herring 4S (Spring Spawner)	Quebec	Forage fish	2018	34
BISKA_HS_5CDE	Big skate	Raja binoculata	Hecate Strait NAFO (DFO 5CDE)	Pacific	Sharks and skates	2021	67
BISKA_QCS_5AB	Big skate	Raja binoculata	Queen Charlotte Sound (DFO 5AB)	Pacific	Sharks and skates	2021	67
BISKA_SOG_4B	Big skate	Raja binoculata	Strait of Georgia (DFO 4B)	Pacific	Sharks and skates	2021	25
BISKA_WCV_3CD	Big skate	Raja binoculata	West coast Vancouver Island (DFO 3CD)	Pacific	Sharks and skates	2021	29
BUTCLA_BC	Butter clam	Saxidomus gigantea	Butter clam (South Coast- Vancouver Island)	Pacific	Invertebrate	2019	68
CAPE_23KLPs	Capelin	Mallotus villosus	Capelin SA2+3KLPs	Newfoundland and Labrador	Forage fish	2020	48
CAPE_4RST	Capelin	Mallotus villosus	Capelin 4RST - East Coast, Gulf of St. Lawrence	Newfoundland and Labrador	Forage fish	2020	60
CLAM_QC_UNS	Softshell clam	Mya arenaria	Softshell clam in Quebec Coastal Waters - Upper North Shore	Quebec	Invertebrate	2019	102
DERED_23K	Redfish species	Sebastes mentella	2+3K Deepwater redfish (S. mentella)	Newfoundland and Labrador	Rockfish and redfish	2020	60
GREN_23KL	Roundnose grenadier	Coryphaenoides rupestris	Grenadier - 23KL	Newfoundland and Labrador	Groundfish	2020	53
GREN_AT_ARC	Roughhead grenadier	Macrourus berglax	Roughhead Grenadier Atlantic and Arctic	Newfoundland and	Groundfish	2020	33

				Labrador				
GRHAL_23KLMNO	Greenland halibut	Reinhardtius hippoglossoides	Greenland Halibut 2-3KLMNO (Turbot) Labrador Shelf - Grand Bank	Newfoundland and Labrador	Flatfish	2020	60
GRHAL_CS	Greenland halibut	Reinhardtius hippoglossoides	Greenland Halibut - Cumberland Sound	Arctic	Flatfish	2020	52
GRURCH_GOSL	Urchin	Strongylocentrotus droebachiensis	Green sea urchin - Northern Estuary and Gulf of St. Lawrence	Quebec	Invertebrate	2019	28
HAD_3LNO	Haddock	Melanogrammus aeglefinus	NAFO 3LNO	Newfoundland and Labrador	Groundfish	2020	67
HAD_5Zjm	Haddock	Melanogrammus aeglefinus	Haddock 5Zjm	Maritimes	Groundfish	2019	50
HAGFISH_4VWX5Z	Hagfish	Myxine glutinosa	Hagfish - 4VWX5Z	Maritimes	Groundfish	2020	31
ICSCAL_STPIERRE	Iceland Scallop	Chlamys islandica	Iceland Scallop - Canada-France Transboundary zone of St. Pierre Bank	Newfoundland and Labrador	Invertebrate	2018	49
INCLA_CC_HM	Manila clam	Venerupis philippinarum	Manila clam in Area 7 (Central Coast - Heiltsuk Manila)	Pacific	Invertebrate	2010	16
JOCRAB_LFA41	Jonah crab	Cancer borealis	Jonah crab - LFA 41 (Offshore)	Maritimes	Invertebrate	2018	23
LITCLA_BC	Littleneck clam	Protothaca staminea	Littleneck clam (South Coast- Vancouver Island)	Pacific	Invertebrate	2019	68
LOB_NLAV_LFA7_to10	American lobster	Homarus americanus	Avalon (LFAs 7-10)	Newfoundland and Labrador	Invertebrate	2019	66
LOB_NLNE_LFA3_to_6	American lobster	Homarus americanus	Northeast (LFAs 3-6)	Newfoundland and Labrador	Invertebrate	2019	66
LOB_NLSC_LFA11_12	American lobster	Homarus americanus	South Coast (LFAs 11-12)	Newfoundland and Labrador	Invertebrate	2019	43
LOB_NLWC_LFA13_14	American lobster	Homarus americanus	West Coast (LFAs 13-14)	Newfoundland and Labrador	Invertebrate	2019	66
LOB_QCNSAI_LFA15-16	American lobster	Homarus americanus	Quebec north shore and Anticosti Island (LFA 15-16)	Quebec	Invertebrate	2018	34
LOB_QCNSAI_LFA17	American lobster	Homarus americanus	Quebec north shore and Anticosti Island (LFA 17)	Quebec	Invertebrate	2018	34
LOB_QCNSAI_LFA18	American lobster	Homarus americanus	Quebec north shore and Anticosti Island (LFA 18)	Quebec	Invertebrate	2018	26
LONOSKA_HS_5CDE	Longnose skate	Raja rhina	Hecate Strait (DFO 5CDE)	Pacific	Sharks and skates	2021	67
LONOSKA_QCS_5AB	Longnose skate	Raja rhina	Queen Charlotte Sound (DFO 5AB)	Pacific	Sharks and skates	2021	67
LONOSKA_SOG_4B	Longnose skate	Raja rhina	Strait of Georgia (DFO 4B)	Pacific	Sharks and skates	2021	25
LONOSKA_WCVI_3CD	Longnose skate	Raja rhina	West coast Vancouver Island (DFO 3CD)	Pacific	Sharks and skates	2021	67
LUFISH_4RS_3Pn	Lumpfish	Cyclopterus Lumpus	Lumpfish - Gulf of St. Lawrence- NAFO Divisions 4RS and Subdivision 3Pn	Quebec	Groundfish	2015	45

LUMP_3KLP	Lumpfish	Cyclopterus lumpus	Lumpfish - 3KLP	Newfoundland and Labrador	Groundfish	2014	31
MANCLA_BC	Manila clam	Venerupis philippinarum	Manila clam (South Coast- Vancouver Island)	Pacific	Invertebrate	2019	68
PACOYST_WCVI_ECVI	Pacific oyster	Crassostrea gigas	Pacific Oyster West Coast Vancouver Island (WCVI) and East Coast Vancouver Island (ECVI)	Pacific	Invertebrate	2018	68
PASAR_PAC	Pacific sardine	Sardinops sagax	Sardine (Pacific)	Pacific	Forage fish	2019	17
POLL_3Ps	Pollock	Pollachius virens	St. Pierre Banks (NAFO 3Ps)	Newfoundland and Labrador	Groundfish	2020	60
POLL_WC_4X5	Pollock	Pollachius virens	Pollock 4X5 (Western Component)	Maritimes	Groundfish	2020	60
PORSHARK_ATL	Porbeagle shark	Lamna nasus	Atlantic Ocean	Maritimes	Sharks and skates	2018	57
RAZCLA_BC	Razor clam	Siliqua patula	Razor clam (South Coast- Vancouver Island)	Pacific	Invertebrate	2019	68
REDFISH_3O	Redfish species	Sebastes fasciatus and Sebastes mentella	Redfish spp. 3O	Newfoundland and Labrador	Rockfish and redfish	2020	60
RERO_3CD_5ABCDE	Redbanded rockfish	Sebastes babcocki	Redbanded Rockfish - 3CD and 5ABCDE	Pacific	Groundfish	2019	79
ROCRAB_CFA23_24_25_26A	Rock crab	Cancer irroratus	Rock Crab LFA 23,24,25,26A	Gulf	Invertebrate	2017	32
ROCRAB_QCW	Rock crab	Cancer irroratus	Quebec coastal waters	Quebec	Invertebrate	2016	22
SECUC_QC	Sea cucumber	Cucumaria frondosa	Sea Cucumber - Quebec inshore waters	Quebec	Invertebrate	2019	11
SESCAL_3Ps	Sea scallop	Placopecten magellanicus	Sea Scallop - St. Pierre Bank- Subdivision 3PS	Newfoundland and Labrador	Invertebrate	2020	51
SESCAL_OFF_SFA26	Sea scallop	Placopecten magellanicus	Sea Scallop - Offshore SFA 26 German, Browns	Maritimes	Invertebrate	2019	21
SESCAL_SGOSL_SFA_21ABC_22_23_24	Sea scallop	Placopecten magellanicus	Scallop - Southern Gulf of St. Lawrence (SFA 21a, b, c, 22, 23, 24)	Gulf	Invertebrate	2016	48
SEURCH_NL	Urchin	Strongylocentrotus droebachiensis	Sea Urchin - Newfoundland	Newfoundland and Labrador	Invertebrate	2017	19
SNCRAB_4R3Pn	Snow crab	Chionoecetes opilio	Division 4R3Pn	Newfoundland and Labrador	Invertebrate	2018	23
SNCRAB_NGOSL_CMA_12A	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 12A	Quebec	Invertebrate	2019	24
SNCRAB_NGOSL_CMA_12B	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 12B	Quebec	Invertebrate	2019	25
SNCRAB_NGOSL_CMA_12C	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 12C	Quebec	Invertebrate	2019	25
SNCRAB_NGOSL_CMA_13	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 13	Quebec	Invertebrate	2019	36
SNCRAB_NGOSL_CMA_14	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 14	Quebec	Invertebrate	2019	36
SNCRAB_NGOSL_CMA_1	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 15	Quebec	Invertebrate	2019	36

5							
SNCRAB_NGOSL_CMA_16	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 16	Quebec	Invertebrate	2019	36
SNCRAB_NGOSL_CMA_16A	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 16A	Quebec	Invertebrate	2019	15
SNCRAB_NGOSL_CMA_17	Snow crab	Chionoecetes opilio	Northern Gulf of St. Lawrence - CMA 17	Quebec	Invertebrate	2019	36
SPDOG_IN	Dogfish	Squalus suckleyi	Dogfish - inside	Pacific	Sharks and skates	2019	84
SPDOG_OUT	Dogfish	Squalus suckleyi	Dogfish - outside	Pacific	Sharks and skates	2019	82
STSHR_SFA4	Striped shrimp	Pandalus montagui	Northern Shrimp SFA 4 montagui	National Capital Region	Invertebrate	2019	17
SUCLA_5A1_5B1	Surf clams	Spisula solidissima	Surf Clam - Iles-de-la-Madeleine	Quebec	Invertebrate	2018	16
SUCLA_NS	Arctic surfclam	Mactromeris polynyma	Stimpson Surf Clams - Quebec coastal waters	Quebec	Invertebrate	2017	24
SUCUC_3PS	Sea cucumber	Cucumaria frondosa	Sea Cucumber - 3Ps	Newfoundland and Labrador	Invertebrate	2017	14
THSKA_3LNO	Thorny skate	Amblyraja radiata	Skate 3LNO	Newfoundland and Labrador	Sharks and skates	2019	34
WHELK_3Ps	Whelk	Buccinum undatum	Whelk - 3Ps	Newfoundland and Labrador	Invertebrate	2020	16
WHELK_4Vs_4W	Whelk	Buccinum undatum	Whelk- 4Vs and 4W	Maritimes	Invertebrate	2019	10
WHELK_QC_1_15	Whelk	Buccinum undatum	Whelk – zones 1 – 15, except 10	Quebec	Invertebrate	2017	33
WHHAKE_3NOPs	White hake	Urophycis tenuis	White Hake - 3NOPs	Newfoundland and Labrador	Groundfish	2020	51
WINFLO_23KL	Winter flounder	Pseudopleuronectes americanus	Winter Flounder 23KL	Newfoundland and Labrador	Groundfish	2020	60
WITFLO_3Ps	Witch flounder	Glyptocephalus cynoglossus	St. Pierre Banks (NAFO 3Ps)	Newfoundland and Labrador	Flatfish	2020	60
YEFLO_5Z	Yellowtail flounder	Limanda ferruginea	Yellowtail Flounder - 5Z	Maritimes	Flatfish	2019	84
ABALONE_PAC	Northern Abalone	Haliotis kamtschatkana	Northern Abalone- Pacific	Pacific	Invertebrate	-	-
ARC_COD	Arctic cod	Boreogadus saida	Arctic Cod	Arctic	Groundfish	-	-
GOBARN_CLAY	Goose barnacles	Pollicipes polymerus	Goose barnacles - Clayoquot Sound	Pacific	Invertebrate	-	-
HAGFISH_4T	Atlantic hagfish	Myxine glutinosa	Southern Gulf of St. Lawrence (NAFO Div. 4T)	Gulf	Groundfish	-	-
KRILL_PAC	Krill	Euphausia pacifica, Thysanoessa spinifera, Thysanoessa inspinata, Thysanoessa	Euphausiids	Pacific	Invertebrate	-	-

		longipes and Thysanoessa rashii among others					
LUMP_2GHL	Lumpfish	Cyclopterus lumpus	Lumpfish - 2GHJ	Newfoundland and Labrador	Groundfish	-	-
PISP_SCAL_PAC	Pink and spiny scallop	Chlamys rubidaand Chlamys hastata	Pink and Spiny Scallop	Pacific	Invertebrate	-	-
RO_TO_CRAB_NL	Toad crab and rock crab	Hyas araneus, Hyas coarctatus, and Cancer irroratus	Toad and Rock Crab – Newfoundland and Labrador region	Newfoundland and Labrador	Invertebrate	-	-
SCAL_GASP	Iceland and sea scallop	Chlamys islandica and Placopecten magellanicus	Gaspe Peninsula (areas 17A1, 17A2, 18B1, 18B2, 18C, 19A)	Quebec	Invertebrate	-	-
SCAL_NSHORE	Iceland and sea scallop	Chlamys islandica and Placopecten magellanicus	North Shore (areas 15, 16A1, 16A2, 16B, 16C, 16D, 16E, 16F, 16G, 16H, 16I, 18A, 18D), most recent SA also covered SFA 17	Quebec	Invertebrate	-	-
SMSKA_NENL_2J3K	Smooth skate	Malacoraja senta	Northeastern Newfoundland and Labrador (NAFO 2J3K)	Newfoundland and Labrador	Sharks and skates	-	-
SMSKA_SGOSL_4T	Smooth skate	Malacoraja senta	Southern Gulf of St. Lawrence (NAFO 4T)	Gulf	Sharks and skates	-	-
THSKA_4T	Thorny skate	Amblyraja radiata	Southern Gulf of St. Lawrence (NAFO 4T)	Gulf	Sharks and skates	-	-
WHELK_2J3K3L4R	Whelk	Buccinum undatum	Whelk - 2J3K3L4R	Newfoundland and Labrador	Invertebrate	-	-
WISKA_3LNOP	Winter skate	Leucoraja ocellata	Winter skate - 3LNOP	Newfoundland and Labrador	Groundfish	-	-

Table A2. Key parameters and results from BSM and CMSY++ stock assessments for 70 stocks with relative biomass time series. Maximum Sustainable Yield (MSY) and carrying capacity (*k*) are expressed in tonnes and all other values express rates (i.e., dimensionless). The values represent the maximum likelihood estimate for each parameter.

	r		*k*		MSY		B/B_{MSY}		F/F_{MSY}	
Stock	**BSM**	**CMSY++**	**BSM**	**CMSY++**	**BSM**	**CMSY++**	**BSM**	**CMSY++**	**BSM**	**CMSY++**
ACRED_23K	0.11	0.05	1171265	2169922	32822	29598	0.43	0.42	0.0004	0.0005
ARFLO_3CD_5ABCDE	0.24	0.19	241236	345258	14496	16528	1.56	1.53	0.4749	0.4246
ATBTUNA_WATL	0.30	0.28	70687	87428	5390	6103	1.03	1.30	0.3925	0.2748
ATHAL_4RST	0.38	0.32	7140	6413	688	518	1.36	1.14	0.6257	0.9934
ATHERR_2J3IKLPs_HFA1_to11	0.25	0.28	233781	215669	14862	15218	0.23	0.28	3.7212	2.3875
ATHERR_4Rfall	0.29	0.35	450000	251227	32654	22291	0.65	0.56	0.4392	0.7536
ATHERR_4Rspring	0.36	0.33	105604	110865	9554	9010	0.69	0.61	0.5443	0.6513
ATHERR_4Sfall	0.43	0.37	24116	30718	2610	2876	1.03	1.18	1.0045	0.7973
BISKA_HS_5CDE	0.16	0.06	18909	71424	779	1048	0.28	0.47	2.0057	0.5876
BISKA_QCS_5AB	0.06	0.06	70607	68300	1043	1037	0.32	0.29	0.1004	0.1327
BISKA_WCV_3CD	0.08	0.06	3753	5563	71	82	0.47	0.42	0.9231	0.9702
CAPE_23KLPs	0.30	0.26	2270861	1527915	171223	100395	0.17	0.14	1.7871	1.1257
CAPE_4RST	0.30	0.31	112653	95049	8533	7296	0.75	0.49	1.2256	2.3619
DERED_23K	0.16	0.11	1165556	1343606	45339	36639	0.45	0.44	0.0003	0.0004
GREN_23KL	0.24	0.25	375869	363941	22801	22546	0.05	0.05	0.2045	0.1931
GREN_AT_ARC	0.19	0.27	189400	110874	8853	7554	0.60	0.46	0.0354	0.0591
GRHAL_23KLMNO	0.16	0.12	582696	789204	24071	24286	0.49	0.46	1.4546	1.6150
GRHAL_CS	0.23	0.20	152505	192371	8996	9656	0.53	0.60	1.1374	0.9159
GRURCH_GOSL	0.29	0.24	8446	9684	620	569	1.12	0.95	0.8683	1.1319
HAD_3LNO	0.35	0.32	347664	365472	30737	28683	0.09	0.16	0.0880	0.0331
HAD_5Zjm	0.45	0.32	192074	242706	21681	19643	1.16	0.91	0.5501	0.7763
HAGFISH_4VWX5Z	0.11	0.07	61719	101483	1679	1686	0.65	0.53	0.3500	0.4484
ICSCAL_STPIERRE	0.32	0.22	14758	24532	1183	1382	1.63	1.53	0.0702	0.0644
INCLA_CC_HM	0.49	0.28	555	968	69	69	1.13	0.87	0.7016	0.9099
JOCRAB_LFA41	0.37	0.22	9296	15289	864	829	0.32	0.68	0.0603	0.0199
LOB_NLAV_LFA7_to10	0.35	0.40	3451	3063	300	308	0.38	0.44	0.3933	0.2894
LOB_NLNE_LFA3_to_6	0.32	0.39	7426	6204	590	601	0.79	0.47	0.3892	0.6921
LOB_NLSC_LFA11_12	0.49	0.41	9585	11901	1171	1205	1.02	0.86	1.3033	1.5057
LOB_NLWC_LFA13_14	0.55	0.39	8858	12504	1218	1210	0.91	0.84	1.8827	2.0537
LOB_QCNSAI_LFA15-16	0.43	0.37	805	1303	87	121	1.07	1.20	1.4799	0.9767
LOB_QCNSAI_LFA17	0.43	0.46	5724	6849	614	782	1.55	1.52	0.8099	0.6445
LOB_QCNSAI_LFA18	0.48	0.42	559	801	67	84	1.38	1.39	1.0665	0.8489
LONOSKA_HS_5CDE	0.10	0.07	7084	11943	171	199	1.12	1.16	0.3823	0.3243
LONOSKA_QCS_5AB	0.10	0.07	7131	12576	186	217	1.07	1.14	0.4426	0.3608
LONOSKA_WCVI_3CD	0.10	0.07	12818	22819	330	386	1.09	1.16	0.4548	0.3700
LUFISH_4RS_3Pn	0.13	0.12	90386	82201	2928	2424	0.96	0.37	0.0413	0.1680
LUMP_3KLP	0.16	0.12	1059	1335	43	41	0.42	0.32	0.0275	0.0511

PASAR_PAC	0.37	0.40	981855	823922	89665	81613	0.05	0.07	43.0941	24.2135
POLL_3Ps	0.38	0.38	29284	42164	2779	4017	0.30	0.18	0.8826	1.8060
POLL_WC_4X5	0.39	0.38	447219	468254	43243	44775	0.52	0.59	0.1558	0.1288
PORSHARK_ATL	0.04	0.04	304174	418984	3289	3981	0.64	0.63	0.0175	0.0147
REDFISH_3O	0.11	0.06	601636	912132	15797	13707	0.67	0.65	0.6621	0.7816
RERO_3CD_5ABCDE	0.03	0.02	119436	154796	747	842	0.46	0.48	0.9026	0.7750
ROCRAB_CFA23_24_25_26A	0.36	0.28	48036	56542	4363	4016	1.12	0.82	0.6801	1.0229
SECUC_QC	0.36	0.28	6993	8484	640	592	0.98	0.81	0.9986	1.3038
SESCAL_3Ps	0.40	0.37	22221	24906	2249	2329	0.24	0.29	3.4065	2.2038
SESCAL_OFF_SFA26	0.49	0.41	5698	6820	697	703	0.35	0.26	2.4728	4.4910
SESCAL_SGOSL_SFA_21ABC_22_23_24	0.34	0.32	3726	3947	314	316	0.42	0.54	0.6560	0.4342
SNCRAB_4R3Pn	0.40	0.42	11933	10499	1176	1105	0.59	0.21	0.5279	3.6968
SNCRAB_NGOSL_CMA_12A	0.47	0.44	1621	1884	190	204	0.62	0.57	0.7575	0.7630
SNCRAB_NGOSL_CMA_12B	0.66	0.45	1708	2655	284	296	0.21	0.51	1.6175	0.2635
SNCRAB_NGOSL_CMA_12C	0.50	0.43	2236	2674	279	289	0.34	0.58	3.0748	1.1762
SNCRAB_NGOSL_CMA_13	0.38	0.37	9611	8944	921	820	0.39	0.19	1.1606	5.4203
SNCRAB_NGOSL_CMA_14	0.67	0.44	3106	4949	520	526	0.52	0.58	2.0132	1.7098
SNCRAB_NGOSL_CMA_15	0.51	0.49	3943	4232	507	514	0.59	0.53	1.7478	1.9606
SNCRAB_NGOSL_CMA_16	0.59	0.42	25222	36530	3688	3811	0.65	0.63	1.4219	1.4140
SNCRAB_NGOSL_CMA_16A	0.55	0.47	2820	3481	391	413	0.35	0.55	3.6699	1.5667
SNCRAB_NGOSL_CMA_17	0.50	0.38	16003	21079	2006	2015	0.62	0.60	1.6651	1.7283
SPDOG_IN	0.02	0.02	1231796	1424775	6894	7635	0.43	0.42	0.0168	0.0158
SPDOG_OUT	0.02	0.02	1884184	2430363	11493	13037	0.41	0.43	0.0363	0.0301
STSHR_SFA4	0.45	0.30	20798	29832	2338	2253	1.38	1.29	0.6085	0.6798
SUCLA_5A1_5B1	0.43	0.37	3586	4334	389	398	1.21	1.19	0.7426	0.7389
SUCLA_NS	0.37	0.30	7402	9135	698	685	0.97	0.98	0.9066	0.9090
SUCUC_3PS	0.43	0.29	21497	36996	2349	2709	1.53	1.51	0.8341	0.7420
THSKA_3LNO	0.14	0.11	457009	543476	15853	14180	0.68	0.60	0.7530	0.9597
WHELK_3Ps	0.47	0.45	32969	31256	3867	3478	1.55	1.43	0.0455	0.0562
WHELK_QC_1_15	0.53	0.47	10782	11642	1439	1362	1.17	0.99	0.7773	0.9994
WHHAKE_3NOPs	0.34	0.32	64959	62107	5564	4992	0.28	0.24	0.6660	1.0009
WITFLO_3Ps	0.32	0.29	23815	25676	1889	1890	0.82	0.72	0.0922	0.1048
YEFLO_5Z	0.51	0.60	138126	97771	17407	14661	0.03	1.00	1.0055	0.0022

Table A3. Key parameters and results from sensitivity analyses based on assessments for 16 invertebrate stocks with high, low and medium resilience. Biomass reference point (B_{MSY}) and carrying capacity (*k*) are expressed in tonnes and all other values express rates (i.e., dimensionless). The values represent the maximum likelihood estimate for each parameter. Stock status is defined as healthy (biomass ≥ 80% B_{MSY}), cautious (40% B_{MSY} < biomass < 80% B_{MSY}), or critical (biomass ≤ 40% B_{MSY}) and overfishing is occurring when $F > F_{MSY}$.
*Denotes assessment where setting the resilience parameter to low or high resilience resulted in a stock status change
** Denotes assessment where setting the resilience parameter to low or high resilience resulted in a change in exploitation state

Stock	Resilience	*r*	*k*	F_{MSY}	B_{MSY}	B/B_{MSY}	F/F_{MSY}	Stock status	Is overfishing occurring?
BUTCLA_BC	High	0.49	10154	0.10	5077	0.21	0.79	Critical	No
	Low	0.06	84474	0.01	42237	0.22	0.73	Critical	No
	Medium	0.19	20532	0.04	10266	0.20	1.12	Critical	Yes**
CLAM_QC_UNS	High	0.70	26486	0.35	13243	1.31	0.05	Healthy	No
	Low	0.06	318795	0.03	159397	0.98	0.06	Healthy	No
	Medium	0.37	38646	0.19	19323	1.16	0.07	Healthy	No
GRURCH_GOSL	High	0.77	3571	0.39	1786	1.10	0.81	Healthy	No
	Low	0.12	21155	0.06	10577	1.18	0.79	Healthy	No
	Medium	0.29	8446	0.15	4223	1.12	0.87	Healthy	No
ICSCAL_STPIERRE	High	0.68	7803	0.34	3902	1.70	0.06	Healthy	No
	Low	0.17	28277	0.08	14138	1.54	0.07	Healthy	No
	Medium	0.32	14758	0.16	7379	1.63	0.07	Healthy	No
INCLA_CC_HM	High	1.21	236	0.61	118	1.31	0.59	Healthy	No
	Low	0.14	1784	0.07	892	1.00	0.83	Healthy	No
	Medium	0.49	555	0.25	277	1.13	0.70	Healthy	No
JOCRAB_LFA41	High	0.75	6106	0.27	3053	0.36	0.04	Critical	No
	Low	0.27	11414	0.11	5707	0.39	0.05	Critical	No
	Medium	0.37	9296	0.12	4648	0.32	0.06	Critical	No
LITCLA_BC	High	0.54	1927	0.22	964	0.41	1.24	Cautious	Yes
	Low	0.06	19997	0.03	9999	0.44	0.97	Cautious	No**
	Medium	0.19	4540	0.08	2270	0.43	1.32	Cautious	Yes
MANCLA_BC	High	0.60	11450	0.30	5725	0.72	1.13	Cautious	Yes
	Low	0.06	131836	0.03	65918	0.66	1.01	Cautious	Yes
	Medium	0.25	24918	0.13	12459	0.70	1.28	Cautious	Yes
RAZCLA_BC	High	0.68	879	0.34	439	0.87	1.01	Healthy	Yes
	Low	0.07	8284	0.03	4142	0.83	1.13	Healthy	Yes
	Medium	0.25	2114	0.13	1057	0.78	1.24	Cautious*	Yes
ROCRAB_CFA23_24_25_26A	High	0.88	21333	0.44	10667	1.22	0.59	Healthy	No
	Low	0.12	135038	0.06	67519	1.03	0.80	Healthy	No
	Medium	0.36	48036	0.18	24018	1.12	0.68	Healthy	No
ROCRAB_QCW	High	0.74	8385	0.37	4193	0.70	0.88	Cautious	No
	Low	0.07	81893	0.03	40946	0.75	0.90	Cautious	No
	Medium	0.25	21825	0.12	10912	0.68	1.04	Cautious	Yes**

SECUC_QC	High	0.77	3806	0.38	1903	1.01	0.84	Healthy	No
	Low	0.21	11051	0.11	5526	0.99	1.02	Healthy	Yes**
	Medium	0.36	6993	0.18	3496	0.98	1.00	Healthy	No
SEURCH_NL	High	0.67	3600	0.33	1800	0.83	1.11	Healthy*	Yes
	Low	0.07	36094	0.04	18047	0.75	1.14	Cautious	Yes
	Medium	0.26	7532	0.13	3766	0.70	1.56	Cautious	Yes
STSHR_SFA4	High	1.05	9739	0.52	4870	1.38	0.57	Healthy	No
	Low	0.16	56132	0.08	28066	1.41	0.62	Healthy	No
	Medium	0.45	20798	0.22	10399	1.38	0.61	Healthy	No
SUCLA_NS	High	0.89	3503	0.45	1751	0.98	0.79	Healthy	No
	Low	0.18	13697	0.09	6848	1.00	0.99	Healthy	No
	Medium	0.37	7402	0.19	3701	0.97	0.91	Healthy	No
SUCUC_3PS	High	0.92	11077	0.46	5539	1.46	0.80	Healthy	No
	Low	0.19	52367	0.10	26183	1.58	0.75	Healthy	No
	Medium	0.43	21497	0.22	10749	1.53	0.83	Healthy	No

Table A4. Summary of BSM and CMSY++ assessment results for 99 Canadian marine stocks previously identified as 'uncertain' in the 2021 Fishery Audit. Corresponding number in reference list indicates the source for relative biomass time series used for BSM assessment. Upper Stock Reference (USR) and Limit Reference Point (LRP) are calculated as 80% and 40% of B_{MSY}, respectively. Biomass reference points (B_{MSY}, USR, LRP) are expressed in tonnes and all other values express rates (i.e., dimensionless). The values represent the maximum likelihood estimate for each parameter. Stock status is defined as healthy (biomass ≥ 80% B_{MSY}), cautious (40% B_{MSY} < biomass < 80% B_{MSY}), or critical (biomass ≤ 40% B_{MSY}) and overfishing is occurring when $F>F_{MSY}$.

Stock	**Assessment**	**Source**	**B/B_{MSY}**	**F/F_{MSY}**	**B_{MSY}**	**USR**	**LRP**	**Stock status**	**Is overfishing occurring?**	**Reliability**
ACRED_23K	BSM	1	0.43	0.00	585633	468506	234253	Cautious	No	4
ARFLO_3CD_5ABCDE	BSM	2	1.56	0.47	120618	96494	48247	Healthy	No	4
ATBTUNA_WATL	BSM	3	1.03	0.39	35344	28275	14137	Healthy	No	4
ATCOD_2GH	CMSY++	-	0.22	2.00	236417	189134	94567	Critical	Yes	1
ATHAL_4RST	BSM	4	1.36	0.63	3570	2856	1428	Healthy	No	3
ATHERR_2J3IKLPs_HFA1_to11	BSM	5	0.23	3.72	116891	93513	46756	Critical	Yes	3
ATHERR_4Rfall	BSM	6	0.65	0.44	225000	180000	90000	Cautious	No	4
ATHERR_4Rspring	BSM	6	0.69	0.54	52802	42242	21121	Cautious	No	4
ATHERR_4Sfall	BSM	7	1.03	1.00	12058	9646	4823	Healthy	Yes	3
ATHERR_4Sspring	CMSY++	-	1.53	0.44	2017	1614	807	Healthy	No	1
BISKA_HS_5CDE	BSM	8	0.28	2.01	9454	7563	3782	Critical	Yes	3
BISKA_QCS_5AB	BSM	8	0.32	0.10	35304	28243	14121	Critical	No	3
BISKA_SOG_4B	CMSY	-	0.52	0.65	1938	1550	775	Cautious	No	1
BISKA_WCV_3CD	BSM	8	0.47	0.92	1877	1501	751	Cautious	No	3
BUTCLA_BC	CMSY++	-	0.20	1.12	10266	8213	4106	Critical	Yes	1
CAPE_23KLPs	BSM	9	0.17	1.79	1135430	908344	454172	Critical	Yes	4
CAPE_4RST	BSM	10	0.75	1.23	56326	45061	22531	Cautious	Yes	4
CLAM_QC_UNS	CMSY++	-	1.16	0.07	19323	15458	7729	Healthy	No	2
DERED_23K	BSM	1	0.45	0.00	582778	466222	233111	Cautious	No	4
GREN_23KL	BSM	11	0.05	0.20	187934	150348	75174	Critical	No	4
GREN_AT_ARC	BSM	12	0.60	0.04	94700	75760	37880	Cautious	No	4
GRHAL_23KLMNO	BSM	13	0.49	1.45	291348	233078	116539	Cautious	Yes	3
GRHAL_CS	BSM	14	0.53	1.14	76252	61002	30501	Cautious	Yes	3
GRURCH_GOSL	BSM	15	1.12	0.87	4223	3378	1689	Healthy	No	3
HAD_3LNO	BSM	16	0.09	0.09	173832	139066	69533	Critical	No	4
HAD_5Zjm	BSM	17	1.16	0.55	96037	76830	38415	Healthy	No	4
HAGFISH_4VWX5Z	BSM	18	0.65	0.35	30859	24687	12344	Cautious	No	3
ICSCAL_STPIERRE	BSM	19	1.63	0.07	7379	5903	2952	Healthy	No	4
INCLA_CC_HM	BSM	20	1.13	0.70	277	222	111	Healthy	No	3

JOCRAB_LFA41	BSM	21	0.32	0.06	4648	3719	1859	Critical	No	4
LITCLA_BC	CMSY++	-	0.43	1.32	2270	1816	908	Cautious	Yes	1
LOB_NLAV_LFA7_to10	BSM	22	0.38	0.39	1726	1380	690	Critical	No	4
LOB_NLNE_LFA3_to_6	BSM	22	0.79	0.39	3713	2970	1485	Cautious	No	4
LOB_NLSC_LFA11_12	BSM	22	1.02	1.30	4792	3834	1917	Healthy	Yes	4
LOB_NLWC_LFA13_14	BSM	22	0.91	1.88	4429	3543	1772	Healthy	Yes	4
LOB_QCNSAI_LFA15-16	BSM	23	1.07	1.48	402	322	161	Healthy	Yes	4
LOB_QCNSAI_LFA17	BSM	23	1.55	0.81	2862	2290	1145	Healthy	No	4
LOB_QCNSAI_LFA18	BSM	23	1.38	1.07	280	224	112	Healthy	Yes	4
LONOSKA_HS_5CDE	BSM	8	1.12	0.38	3542	2834	1417	Healthy	No	4
LONOSKA_QCS_5AB	BSM	8	1.07	0.44	3566	2852	1426	Healthy	No	4
LONOSKA_SOG_4B	CMSY++	-	1.03	0.22	730	584	292	Healthy	No	2
LONOSKA_WCVI_3CD	BSM	8	1.09	0.45	6409	5127	2564	Healthy	No	4
LUFISH_4RS_3Pn	BSM	24	0.96	0.04	45193	36154	18077	Healthy	No	4
LUMP_3KLP	BSM	25	0.42	0.03	529	423	212	Cautious	No	4
MANCLA_BC	CMSY++	-	0.70	1.28	12459	9967	4984	Cautious	Yes	1
PACOYST_WCVI_ECVI	CMSY++	-	0.36	0.90	122311	97848	48924	Critical	No	1
PASAR_PAC[14]	BSM	26	0.05	43.09	490928	392742	196371	Critical	Yes	4
POLL_3Ps	BSM	27	0.30	0.88	14642	11714	5857	Critical	No	4
POLL_WC_4X5	BSM	28	0.52	0.16	223610	178888	89444	Cautious	No	4
PORSHARK_ATL	BSM	29	0.64	0.02	152087	121670	60835	Cautious	No	4
RAZCLA_BC	CMSY++	-	0.78	1.24	1057	846	423	Cautious	Yes	1
REDFISH_3O	BSM	30	0.67	0.66	300818	240654	120327	Cautious	No	4
RERO_3CD_5ABCDE	BSM	31	0.46	0.90	59718	47774	23887	Cautious	No	3
ROCRAB_CFA23_24_25_26A	BSM	32	1.12	0.68	24018	19214	9607	Healthy	No	4

[14] The BSM assessment for Pacific Sardine northern sub-population in the eastern Pacific Ocean (also known as the California Current Ecosystem stock) estimated fishing rates that were 43 times beyond sustainable levels (driven largely by Mexican catches). In order to explain the high F/F_{MSY} values, we observe an annual increase from 6,275 to 33,843 tonnes, which is a relatively small increase in absolute terms but about 540% in relative terms. The model incorporates the effects of depensation (see Equation 2) reflected by a linear decline of $curF_{MSY}$ when biomass falls below 0.25k (Hutchings, 2014, 2015). The analysis provides both F_{MSY}= 0.184 and $curF_{MSY}$= 0.019 but selects $curF_{MSY}$ as the source of the trigger for management. However, without depensation accounted for, F/F_{MSY} still exceeds sustainable rates by around 4.5 times. Both estimates warn managers that continued fishing at this low biomass level is unsustainable and will prevent stock recovery. Since 2013, sardines have been largely absent from BC waters (DFO, 2021), which suggests that the population may be severely depleted and experiencing reduced migration patterns. An updated assessment process is anticipated to start in 2022, with a release of the benchmark assessment in 2023.

ROCRAB_QCW	CMSY++	-	0.68	1.04	10912	8730	4365	Cautious	Yes	1
SECUC_QC	BSM	33	0.98	1.00	3496	2797	1399	Healthy	No	4
SESCAL_3Ps	BSM	34	0.24	3.41	11111	8889	4444	Critical	Yes	3
SESCAL_OFF_SFA26	BSM	35	0.35	2.47	2849	2279	1140	Critical	Yes	3
SESCAL_SGOSL_SFA_21ABC_22_23_24	BSM	36	0.42	0.66	1863	1490	745	Cautious	No	4
SEURCH_NL	CMSY++	-	0.70	1.56	3766	3013	1506	Cautious	Yes	1
SNCRAB_4R3Pn	BSM	37	0.59	0.53	5966	4773	2387	Cautious	No	4
SNCRAB_NGOSL_CMA_12A	BSM	38	0.62	0.76	811	648	324	Cautious	No	4
SNCRAB_NGOSL_CMA_12B	BSM	38	0.21	1.62	854	683	342	Critical	Yes	4
SNCRAB_NGOSL_CMA_12C	BSM	38	0.34	3.07	1118	894	447	Critical	Yes	4
SNCRAB_NGOSL_CMA_13	BSM	38	0.39	1.16	4805	3844	1922	Critical	Yes	4
SNCRAB_NGOSL_CMA_14	BSM	38	0.52	2.01	1553	1242	621	Cautious	Yes	4
SNCRAB_NGOSL_CMA_15	BSM	38	0.59	1.75	1972	1577	789	Cautious	Yes	4
SNCRAB_NGOSL_CMA_16	BSM	38	0.65	1.42	12611	10089	5044	Cautious	Yes	4
SNCRAB_NGOSL_CMA_16A	BSM	38	0.35	3.67	1410	1128	564	Critical	Yes	4
SNCRAB_NGOSL_CMA_17	BSM	38	0.62	1.67	8002	6401	3201	Cautious	Yes	4
SPDOG_IN	BSM	39	0.43	0.02	615898	492718	246359	Cautious	No	3
SPDOG_OUT	BSM	39	0.41	0.04	942092	753674	376837	Cautious	No	3
STSHR_SFA4	BSM	40	1.38	0.61	10399	8319	4160	Healthy	No	3
SUCLA_5A1_5B1	BSM	41	1.21	0.74	1793	1434	717	Healthy	No	4
SUCLA_NS	BSM	42	0.97	0.91	3701	2961	1480	Healthy	No	3
SUCUC_3PS	BSM	43	1.53	0.83	10749	8599	4299	Healthy	No	3
THSKA_3LNO	BSM	13	0.68	0.75	228504	182803	91402	Cautious	No	4
WHELK_3Ps	BSM	44	1.55	0.05	16485	13188	6594	Healthy	No	3
WHELK_4Vs_4W	CMSY++	-	1.15	1.12	2457	1965	983	Healthy	Yes	1
WHELK_QC_1_15	BSM	45	1.17	0.78	5391	4313	2156	Healthy	No	3
WHHAKE_3NOPs	BSM	46	0.28	0.67	32479	25983	12992	Critical	No	3
WINFLO_23KL	CMSY++	-	0.19	0.40	4938	3951	1975	Critical	No	1
WITFLO_3Ps	BSM	47	0.82	0.09	11907	9526	4763	Healthy	No	4
YEFLO_5Z	BSM	48	0.03	1.01	69063	55250	27625	Critical	Yes	4
ABALONE_PAC	-	-	-	-	-	-	-	Uncertain	Uncertain	-
ARC_COD	-	-	-	-	-	-	-	Uncertain	Uncertain	-
GOBARN_CLAY	-	-	-	-	-	-	-	Uncertain	Uncertain	-
HAGFISH_4T	-	-	-	-	-	-	-	Uncertain	Uncertain	-
KRILL_PAC	-	-	-	-	-	-	-	Uncertain	Uncertain	-
LUMP_2GHL	-	-	-	-	-	-	-	Uncertain	Uncertain	-
PISP_SCAL_PAC	-	-	-	-	-	-	-	Uncertain	Uncertain	-
RO_TO_CRAB_NL	-	-	-	-	-	-	-	Uncertain	Uncertain	-

SCAL_GASP	-	-	-	-	-	-	-	Uncertain	Uncertain	-
SCAL_NSHORE	-	-	-	-	-	-	-	Uncertain	Uncertain	-
SMSKA_NENL_2J3K	-	-	-	-	-	-	-	Uncertain	Uncertain	-
SMSKA_SGOSL_4T	-	-	-	-	-	-	-	Uncertain	Uncertain	-
THSKA_4T	-	-	-	-	-	-	-	Uncertain	Uncertain	-
WHELK_2J3K3L4R	-	-	-	-	-	-	-	Uncertain	Uncertain	-
WISKA_3LNOP	-	-	-	-	-	-	-	Uncertain	Uncertain	-

References from 'Source' column in Table A4:

1. DFO (2021) Stock status of Redfish in NAFO SA 2 + Divs. 3K DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/021
2. Grandin, C., & Forrest, R. (2017) Arrowtooth Flounder (*Atheresthes stomias*) Stock Assessment for the West Coast of British Columbia DFO Can. Sci. Advis. Sec. Res. Doc. 2017/025. v + 87 p.
3. ICCAT (2017) Report of the 2017 ICCAT Bluefin Stock Assessment Meeting BFT Stock Assessment Meeting - Madrid 2017
4. DFO (2019) Stock Assessment of Gulf of St. Lawrence (4RST) Atlantic Halibut in 2018 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/038
5. DFO (2019) Assessment of Newfoundland east and south coast Herring in 2017 and 2018 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/049
6. DFO (2021) Assessment of the West Coast of Newfoundland (NAFO Division 4R) Herring Stock Assessment in 2019 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/005
7. DFO (2019) Assessment of the Quebec North Shore (Division 4S) herring stocks in 2018 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/037
8. King, J.R., et al. (2015) Big Skate (*Raja binoculata*) and Longnose Skate (*R. rhina)* stock assessments for British Columbia DFO Can. Sci. Advis. Sec. Res. Doc. 2015/070. ix + 329 p.
9. Bourne, C., et al. (2021) Assessment of Capelin (*Mallotus villosus*) in 2J3KL to 2018 DFO Can. Sci. Advis. Sec. Res. Doc. 2021/055. iv + 39 p.
10. DFO (2018) Assessment of the Estuary and Gulf of St. Lawrence (Divisions 4RST) Capelin Stock in 2017 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/037
11. Simpson, M.R., et al. (2011) Recovery potential assessment of Roundnose Grenadier (*Coryphaenoides rupestris* Gunnerus, 1765) in Northwest Atlantic waters DFO Can. Sci. Advis. Sec. Res. Doc. 2011/077
12. NAFO (2019) Report of the Scientific Council Meeting. 31 May -13 June 2019. Halifax, Nova Scotia NAFO SCS Doc. 19/20
13. Northwest Atlantic Fisheries Organization (2020) Report of the Scientific Council, 28 May -12 June 2020 NAFO SCS Doc. 20/14
14. DFO (2008) Cumberland Sound Greenland Halibut (Turbot) Inshore Fishery DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2008/040

15 DFO (2016) Assessment of the Green Sea Urchin Fishery in the Northern Estuary and Gulf of St. Lawrence in 2015 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/054
16 DFO (2018) Stock Assessment of NAFO Divisions 3LNO Haddock DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/009
17 TRAC (2020) Eastern Georges Bank Haddock TRAC Status Report 2020/02
18 DFO (2018) Status of the Hagfish (*Myxine glutinosa*) Fishery in the Maritimes Region DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/048
19 DFO (2021) An Assessment of Iceland Scallop (*Chlamys islandica*) in the Strait of Belle Isle DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/009
20 DFO (2011) Assessment update of Manila Clams in Area 7 of the Central Coast of British Columbia and Evaluation of the Manila Clam Fisheries Management Strategy DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/077
21 DFO (2009) Assessment of Jonah Crab in Lobster Fishing Area 41 (4X + 5Zc) DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/034
22 DFO (2021) Assessment of American Lobster in Newfoundland DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2021/008
23 DFO (2019) Assessment of lobster (*Homarus americanus*) on the North Shore (LFAs 15, 16 and 18) and at Anticosti Island (LFA 17), Quebec, in 2018 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/059
24 Gauthier. J., et al. (2017) Assessment of Lumpfish (*Cyclopterus lumpus*) in the Gulf of St. Lawrence (3Pn, 4RS) in 2015 DFO Can. Sci. Advis. Sec. Res. Doc. 2017/051
25 Simpson, M.R., et al. (2016) A pre-COSEWIC assessment of the Common Lumpfish (Cyclopterus lumpus, Linnaeus 1758) in Canadian Atlantic and Arctic waters DFO Can. Sci. Advis. Sec. Res. Doc. 2016/068
26 DFO (2021) Harvest Advice for Pacific Sardine (*Sardinops sagax*) in British Columbia Waters for 2021 DFO Can. Sci. Advis. Sec. Sci. Resp. 2021/034
27 DFO (2019) Stock Assessment of NAFO Subdivision 3Ps Pollock (*Pollachius virens*) DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/039
28 DFO (2020) Harvest Control Rule Update for Western Component (4Xopqrs5) Pollock (*Pollachius virens*) DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/022
29 ICCAT (2009) Report of the 2009 Porbeagle stock assessment meeting - Copenhagen, Denmark, June 22 to 27, 2009. SCRS/2009/014 – Sharks Stock Assessment.
30 NAFO (2019) Redfish in Division 3O - Advice June 2019 for 2020-2022 SC 31 May _ 13 June 2019
31 Anderson, S.C., et al. (2019) A reproducible data synopsis for over 100 species of British Columbia groundfsh. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/041. vii +321 p.
32 DFO (2019) Update to 2017 of the fishery indicators for rock crab (*Cancer irroratus*) in the southern Gulf of St. Lawrence DFO Can. Sci. Advis. Sec. Sci. Resp. 2019/007
33 DFO (2020) Update of sea cucumber stock status indicators for Areas B and C in the Gaspe Peninsula in 2019 DFO Can. Sci.

Advis. Sec. Sci. Resp. 2020/038
34 Coughlan, E., et al. (2020) An Assessment of Sea Scallop (*Placopecten magellanicus*) on St. Pierre Bank DFO Can. Sci. Advis. Sec. Res. Doc. 2020/005. iv + 27 p.
35 DFO (2020) Stock Status Update of Browns Bank North Scallops (*Placopecten magellanicus*) for the 2020 Fishing Season DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/042
36 Niles, M., et al. (2021) Scallop Fishery Assessment of the Southern Gulf of St. Lawrence in 2018: Commercial Fishery and Survey Data DFO Can. Sci. Advis. Sec. Res. Doc. 2021/038. xii + 178 p.
37 DFO (2019) Assessment of Newfoundland and Labrador (Divisions 2HJ3KLNOP4R) Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/041.
38 DFO (2020) Assessment of the Estuary and Northern Gulf of St. Lawrence (Areas 13 to 17, 12A, 12B, 12C and 16A) Snow Crab Stocks in 2019 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2020/050
39 DFO (2010) Assessment of Spiny Dogfish (*Squalus acanthias*) in British Columbia in 2010 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/057
40 DFO (2020) Stock status update of striped shrimp (*Pandalus montagui*) in SFA 4 DFO Can. Sci. Advis. Sec. Sci. Resp. 2020/016
41 Brulotte, S. (2020) Stock assessment of Atlantic Surfclam, *Spisula solidissima*, of the les-de-la Madeleine in 2018 _ Methodology and Results DFO Can. Sci. Advis. Sec. Res. Doc. 2020/010. ix + 43 p.
42 DFO (2018) Assessment of the Stimpson's surfclam stocks of Quebec coastal waters in 2017 DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/022
43 DFO (2018) Sea Cucumber stock status update in NAFO Subdivision 3Ps DFO Can. Sci. Advis. Sec. Sci. Resp. 2018/010
44 DFO (2013) Subdivision 3Ps offshore whelk: a preliminary assessment of male size at maturity DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/066.
45 DFO (2018) Assessment of the whelk fishery in Quebec's inshore waters DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/028.
46 Simpson, M.R, & Miri, C.M. (2021) An Assessment of White Hake (*Urophycis tenuis*, Mitchill 1815) in NAFO Divisions 3N, 3O, and Subdivision 3Ps NAFO SCR Doc. 21/022
47 Wheeland, L., et al. (2019) An Assessment of Witch Flounder (*Glyptocephalus cynoglossus*) in NAFO Subdivision 3Ps from Catch and Survey Information. DFO Can. Sci. Advis. Sec. Res. Doc. 2018/064. vi + 34 p.
48 TRAC (2020) Georges Bank Yellowtail Flounder TRAC Status Report 2020/03

Table A5. Key parameters and results, including upper (UCL) and lower (LCL) 95% confidence limits, from assessments of nine snow crab management units in the Northern Gulf of St. Lawrence (12A, 12B, 12C, 13, 14, 15, 16, 16A and 17) and an assessment based on combined areas (SNCRAB_NGOSL_ALL). Carrying capacity (*k*) is expressed in tonnes and all other values express rates (i.e., dimensionless). The values represent the maximum likelihood estimate for each parameter.

*Denotes assessment where the estimate of B/B_{MSY} does not fall within the range estimated by the assessment based on combined areas

Stock name	***r***	**LCL**	**UCL**	***k***	**LCL**	**UCL**	**B/B_{MSY}**	**LCL**	**UCL**	**F/F_{MSY}**	**LCL**	**UCL**
SNCRAB_NGOSL_ALL	0.48	0.34	0.67	59163	41852	85685	0.60	0.43	0.79	1.77	1.11	3.15
SNCRAB_NGOSL_CMA_12A	0.47	0.32	0.68	1621	1052	2718	0.62	0.38	0.88	0.76	0.44	1.54
SNCRAB_NGOSL_CMA_12B	0.66	0.44	0.95	1708	1213	2597	0.21*	0.13*	0.33*	1.62	0.58	4.38
SNCRAB_NGOSL_CMA_12C	0.50	0.35	0.73	2236	1490	3324	0.34	0.20	0.58	3.07	1.11	8.88
SNCRAB_NGOSL_CMA_13	0.38	0.27	0.56	9611	5958	16946	0.39	0.23	0.60	1.16	0.53	3.09
SNCRAB_NGOSL_CMA_14	0.67	0.47	0.89	3106	2334	4429	0.52	0.37	0.73	2.01	1.26	3.85
SNCRAB_NGOSL_CMA_15	0.51	0.36	0.72	3943	2635	6419	0.59	0.40	0.83	1.75	0.97	3.52
SNCRAB_NGOSL_CMA_16	0.59	0.41	0.84	25222	17487	37138	0.65	0.48	0.82	1.42	0.93	2.24
SNCRAB_NGOSL_CMA_16A	0.55	0.37	0.80	2820	1981	4293	0.35	0.23	0.51	3.67	1.64	8.57
SNCRAB_NGOSL_CMA_17	0.50	0.35	0.72	16003	10755	23607	0.62	0.44	0.86	1.67	1.08	2.84