Proceedings of the Technical Expertise in Stock Assessment (TESA) Workshop on Risk Uncertainty and Stock Summaries, 27-31 January 2020, Ottawa, Ontario

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ACRONYMS

***B_{lim}*:** Common name for biomass limit reference point (Australia, ICES, NAFO)

***B_{MSY}*:** Biomass associated with the production of maximum sustainable yield (all jurisdictions)

DFO: Fisheries and Oceans Canada

ERAEF: Ecological Risk Assessment for the Effects of Fishing

***F_{lim}*:** Common name for fishing mortality rate limit reference point (Australia, ICES, NAFO)

***F_{MSY}*:** Fishing mortality associated with the production of maximum sustainable yield (all jurisdictions)

FAO: Food and Agriculture Organization of the United Nations

FRDC: Fisheries Research Development Corporation (Australia)

HCR: Harvest control rule, referred to as a harvest decision rule in Canadian policy

ICES: International Council for the Exploration of the Sea

IPCC: Intergovernmental Panel on Climate Change

LRP: Limit reference point, based in biomass (DFO 2009)

MSY: maximum sustainable yield (all jurisdictions)

PA Policy: Refers to Canada's national Precautionary Approach policy (DFO 2009)

RR: Removal reference (DFO 2009)

SFF: Sustainable Fisheries Framework (policy, Canada; DFO, 2018a)

Target: Target reference point, based in biomass or proxies

TRP: Target reference point (DFO 2009)

USR: Upper stock reference (DFO 2009)

WSP: Refers to Canada's Wild Salmon Policy (DFO 2005)

ABSTRACT

Kronlund, A.R., Duplisea, D.E., Marentette, J.M., Thompson, S., Olmstead, M. and Ladell, J. 2022. Proceedings of the Technical Expertise in Stock Assessment (TESA) Workshop on Risk, Uncertainty and Stock Summaries, 27-31 January 2020, Ottawa, Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 3448: ix + 101 p.

The Technical Expertise in Stock Assessment (TESA) group of Fisheries and Oceans Canada (DFO) held a national workshop on ‘Uncertainty and Risk in Fisheries Science Advice, and Standardized Stock Summaries’, in Ottawa, ON from the 27th to 31st of January, 2020. The workshop was split into two parts, with the first three days addressing uncertainty and risk in fisheries science advice. The goal of Part I was to explore uncertainty and risk evaluation, and the communication of both concepts in fisheries science and resource management. Part II of the workshop was focused on the discussion of standardized stock summaries. The goal was to debate the strengths and weaknesses of the present reporting system (both the process and the documentation) for fisheries science information and advice, assess stock summary sheets developed in other jurisdictions and make suggestions for a stock summary format intended to address shortcoming of currently used formats and meet the anticipated requirements for content related to the Fish Stocks provisions of the Fisheries Act. These Proceedings include presentations, summaries of the breakout exercises, a candidate stock summary sheet and recommendations on uncertainty, risk and stock summaries for possible application by DFO. Public materials are available at: https://sites.google.com/view/riskandstocksummary/home.

RÉSUMÉ

Kronlund, A.R., Duplisea, D.E., Marentette, J.M., Thompson, S., Olmstead, M. and J. Ladell. 2022. Proceedings of the Technical Expertise in Stock Assessment (TESA) Workshop on Risk, Uncertainty and Stock Summaries, 27-31 January 2020, Ottawa, Ontario. Can. Tech. Rep. Fish. Aquat. Sci. 3448: ix + 101 p.

Du 27 au 31 janvier 2020, le groupe d'expertise technique en évaluation des stocks (ETES) de Pêches et Océans Canada (MPO) a tenu à Ottawa, en Ontario, un atelier national intitulé « Incertitude et risque dans les avis scientifiques sur les pêches et les résumés normalisés des stocks ». L'atelier était divisé en deux parties, et les trois premières journées étaient consacrées à l'incertitude et au risque dans les avis scientifiques sur les pêches. La première partie de l'atelier avait comme objectif d'explorer l'évaluation de l'incertitude et du risque, ainsi que la communication de ces deux concepts dans les domaines des sciences halieutiques et de la gestion des ressources. La deuxième partie de l'atelier portait sur la discussion des résumés normalisés des stocks. L'objectif était de débattre des forces et des faiblesses de l'actuel système de production de rapports (autant le processus que la documentation) sur les informations et les avis en matière de sciences halieutiques, d'évaluer les fiches sur les résumés des stocks élaborés dans d'autres administrations, et de suggérer des formats de résumé des stocks qui permettraient de combler les lacunes des formats utilisés actuellement, ainsi que de répondre aux exigences de contenu liées aux dispositions sur les stocks de poissons prévues par la Loi sur les pêches Le présent compte rendu comprend les présentations, les résumés des exercices en petits groupes, une fiche sur les résumés des stocks de candidats, ainsi que des recommandations sur l'incertitude, le risque et les résumés de stock en vue d'une application possible par le MPO. On peut consulter les documents publics à l'adresse suivante: https://sites.google.com/view/riskandstocksummary/home.

INTRODUCTION

PURPOSE

This report documents the Fisheries and Oceans Canada (DFO) workshop titled “Risk Uncertainty and Stock Summaries” held 27-31 January 2020 in Ottawa, Ontario. The workshop was delivered through the Technical Expertise in Stock Assessment (TESA) committee and the Fish Population Science Branch, National Capital Region (NCR). The TESA committee has had a mandate since 2009 to provide workshops and training related to fisheries stock assessment to Fisheries and Oceans Canada (DFO) staff. The workshop was chaired by A.R. Kronlund (NCR) and D.E. Duplisea (TESA). Over 35 participants from all DFO Regions attended the workshop (Appendix 1). Dr. Randall Peterman (Professor Emeritus and Former Canada Research Chair in Fisheries Risk Assessment and Management, Simon Fraser University) attended as an invited external expert and keynote speaker at the workshop.

Terms of Reference for the workshop appear in Appendix 2. The workshop was presented in two parts: risk and uncertainty in fisheries (Part I, 27-29 January 2020) and stock summaries (Part II, 30-31 January 2020).

The motivation for holding the workshop was provided by amendments to the *Fisheries Act* enacted when Bill C-68 received Royal Assent on 21 June 2019. The amendments include new Fish Stocks provisions that introduced legal obligations to manage stocks at levels necessary to promote sustainability, avoid limit reference points, and/or institute plans to rebuild fish stocks while considering the biology of the fish and environmental conditions facing the stock. The legislation applies to stocks that are prescribed under regulations.

Table 1: Text of the Fish Stocks provisions of Canada’s Fisheries Act in both English and French.

Fish Stocks **Measures to maintain fish stocks** **6.1 (1)** In the management of fisheries, the Minister shall implement measures to maintain major fish stocks at or above the level necessary to promote the sustainability of the stock, taking into account the biology of the fish and the environmental conditions affecting the stock. **Limit reference point** **2)** If the Minister is of the opinion that it is not feasible or appropriate, for cultural reasons or because of adverse socio-economic impacts, to implement the measures referred to in subsection (1), the Minister shall set a limit reference point and implement measures to maintain the fish stock above that point, taking into account the biology of the fish and the environmental conditions affecting the stock. **Publication of decision** **(3)** If the Minister sets a limit reference point in accordance with subsection (2), he or she shall publish the decision to do so, within a reasonable time and with reasons, on the	**Stocks de poissons** **Mesures pour maintenir les stocks de poissons** **6.1 (1)** Dans sa gestion des pêches, le ministre met en oeuvre des mesures pour maintenir les grands stocks de poissons au moins au niveau nécessaire pour favoriser la durabilité des stocks, en tenant compte de la biologie du poisson et des conditions du milieu qui touchent les stocks. **Point de référence limite** **(2)** S’il estime qu’il n’est pas possible ou qu’il n’est pas indiqué, en raison de facteurs culturels ou de répercussions socioéconomiques négatives, de mettre en oeuvre les mesures visées au paragraphe (1), le ministre établit un point de référence limite et met en oeuvre des mesures pour maintenir le stock de poissons au-dessus de ce point, en tenant compte de la biologie du poisson et des conditions du milieu qui touchent le stock. **Publication de la décision** **(3)** S’il établit un point de référence limite au titre du paragraphe (2), le ministre publie sa décision motivée, dans un délai raisonnable, sur le site Internet du ministère des Pêches et des Océans. **Plan de rétablissement**

Internet site of the Department of Fisheries and Oceans. **Plan to rebuild** **6.2 (1)** If a major fish stock has declined to or below its limit reference point, the Minister shall develop a plan to rebuild the stock above that point in the affected area, taking into account the biology of the fish and the environmental conditions affecting the stock, and implement it within the period provided for in the plan. **Amendment** **(2)** If the Minister is of the opinion that such a plan could result in adverse socio-economic or cultural impacts, the Minister may amend the plan or the implementation period in order to mitigate those impacts while minimizing further decline of the fish stock**.** **Endangered or threatened species** **(3)** Subsection (1) does not apply if the affected fish stock is an endangered species or a threatened species under the *Species at Risk Act* or if the implementation of international management measures by Canada does not permit it. **Publication of decision** **(4)** If the Minister amends a plan in accordance with subsection (2) or decides not to make one in accordance with subsection (3), he or she shall publish the decision to do so, within a reasonable time and with reasons, on the Internet site of the Department of Fisheries and Oceans. **Restoration measures** **(5)** In the management of fisheries, if the Minister is of the opinion that the loss or degradation of the stock's fish habitat has contributed to the stock's decline, he or she shall take into account whether there are measures in place aimed at restoring that fish habitat. **Regulations** **6.3** The major fish stocks referred to in sections 6.1 and 6.2 are to be prescribed by regulations.	**6.2 (1)** Si un grand stock de poissons a diminué jusqu'au point de référence limite pour ce stock ou se situe sous cette limite, le ministre élabore un plan visant à rétablir le stock au-dessus de ce point de référence dans la zone touchée, en tenant compte de la biologie du poisson et des conditions du milieu qui touchent le stock, et met en oeuvre ce plan dans la période qui y est prévue. **Modification** **(2)** S'il estime que le plan pourrait entraîner des répercussions socioéconomiques ou culturelles négatives, le ministre peut le modifier ou en modifier la période de mise en oeuvre afin d'atténuer ces répercussions et de minimiser le déclin du stock de poissons**.** **Espèce menacée ou en voie de disparition** **(3)** Le paragraphe (1) ne s'applique pas si le stock de poissons touché est une espèce en voie de disparition ou une espèce menacée aux termes de la *Loi sur les espèces en péril* ou si la mise en oeuvre de mesures de gestion internationales par le Canada ne le permet pas. **Publication de la décision** **(4)** S'il modifie le plan mis en oeuvre en vertu du paragraphe (2) ou décide de ne pas en élaborer un en application du paragraphe (3), le ministre publie, dans un délai raisonnable, sa décision motivée sur le site Internet du ministère des Pêches et des Océans. **Mesures de restauration** **(5)** Dans sa gestion des pêches, s'il est d'avis que la perte ou la dégradation de l'habitat du poisson du stock concerné a joué un rôle dans le déclin du stock, le ministre tient compte de l'existence de mesures destinées à restaurer cet habitat. **Règlements** **6.3** Les grands stocks de poissons visés par les articles 6.1 et 6.2 sont prévus par règlement.

The text of the new Fish Stocks provisions (Table 1) raises several questions related to uncertainty, risk and reporting that will affect Science Sector activities. For example:

1. How is Section 6.1(1) to be interpreted with respect to a management objective to maintain stocks at "sustainable" levels? Similarly, what does it mean to *"maintain the fish stock at or above [the limit reference point]"* under s. 6.2(1)?

2. How are uncertainty and risk tolerance related to the criteria applied by scientists to determine status or enable the selection of harvest strategies?
3. What does it mean to take "*into account the biology of the fish and the environmental conditions affecting the stock*"? Is this meant to signal the need to consider uncertainty, and/or to allow adjustment of biological reference points under changing environmental conditions?

Evaluation of the uncertainties and risks inherent in fisheries management systems informs decision-making. Likewise, reporting of fisheries management performance with respect to legal obligations and policy intent also involves consideration of both factors. Like most jurisdictions, public reporting of the state of fish stocks in Canada is focused on indicators of current stock status. Unlike most jurisdictions, the highest priority has traditionally been given to status against what could be called biomass or "*B*-based" reference points (stock status zone, based on biomass or some abundance proxy) as opposed to fishing mortality or "*F*-based" reference points (i.e., the Removal Reference (RR) in the PA Policy), although information on this element is available in downloadable Excel files of Sustainability Survey data (DFO 2018a). The reasons for a Canadian focus on "*B*-based" reference points and the objectives they represent could vary. Canada has no terminology for different levels of "*F*-based" fishery status, apart from noting whether removals are either "at or below" versus "exceeds" the RR (DFO 2009). Public reporting systems in Australia, New Zealand, ICES (International Council for the Exploration of the Sea) and the United States report status against axes of both biomass and fishing mortality, either separately or in combination (and with flexibility for relevant proxies, Marentette and Kronlund 2020).

Marentette and Kronlund (2020) recommended that operational guidelines for the Science Sector should include practices for standardized reporting of performance metrics closely tied to evidence required to support the implementation of Fish Stocks provisions, namely sections 6.1(1), 6.1(2) and 6.2 (Table 1). Standardized reporting may also help to address concerns expressed about accessibility and transparency of Canadian fisheries science and stock assessments (Baum and Fuller, 2016) by providing consistently formatted information and possibly reducing the time and translation costs to produce published documents. Standardized approaches also allow consideration of database applications for capturing the source information and flexibly generating reports to serve a variety of audiences.

WORKSHOP ORGANIZATION

The workshop was partitioned into presentations from Regional and NCR staff, and "breakout" exercises. Dr. Peterman provided a keynote address and a concluding presentation. Seven breakout exercises were prepared for completion during the workshop by groups of participants. For each exercise, each group summarized their results on flip charts and reported back to plenary. Groups were re-mixed for each exercise to provide a variety of participant interactions with the constraint that each group had representatives from each DFO region. Breakout group discussion was facilitated by NCR participants. Preparation for the workshop involved completion of a "homework" exercise distributed to participants prior to the workshop. The homework provided participants with practice completing a stock summary similar to one used internationally. This report documents the proceedings of the workshop but is not intended to be a chronological record. Workshop organization and logistics were coordinated by Susan Thompson (NCR, TESA Coordinator) and Melissa Olmstead (NCR). Meeting records are archived by the TESA committee.

Table 2. List of presentations and presenters for Part I and II.

Presentation Title	Presenters
Part I – Uncertainty and Risk	
Keynote Address - Some considerations about stock/risk assessment, risk communication, and risk management	Randall Peterman
Risk in fisheries: Summary of Francis and Shotton (1997)	Rob Kronlund
The PA as a Risk Management Framework: Examples from Many Jurisdictions	Julie Marentette
How Risk is Considered in the ICES Precautionary and MSY Approaches	Daniel Ricard
Implementation of the Fish Stocks Provisions – Thoughts on Risk and Uncertainty	Marc Clemens Amy Lebeau
How the IPCC Deals with Risk	Kendra Holt
Risk Equivalency, Buffers, and Conditioning Risk to Various Factors	Marie-Julie Roux
Indigenous Knowledge Systems Across Canada: Insights for Understanding Diverse Perspectives on Risk	Steven Alexander
Risk Applications: Pacific Salmon Arctic Fisheries and Climate Change Groundfish management procedure framework Risk-based Management of Scallop Fisheries	 Ann-Marie Huang, Carrie Holt Xinhua Zhu Robyn Forrest, Sean Anderson Jessica Sameoto
Black Swans and Do We Need to Consider them in Risk-based Advice and Management?	Sean Anderson
Fish Stocks provisions and the Record of Evidence	Amy Lebeau
Modern collaborative tools for automatically generating standardised documents	Sean Anderson on behalf of Andrew Edwards
Part II – Stock Summaries	
Introduction to Stock Summaries	Rob Kronlund, Julie Marentette
Regional Summaries Central and Arctic Region Gulf Region Maritimes Region National Capital Region Newfoundland and Labrador Region	

Presentation Title	Presenters
Pacific Region	
Stock Summary Information for Ecosystems	Pierre Pepin
Science Outputs, Stock Summaries and the Record of Evidence	Julie Marentette
CSAS Renewal	Estelle Couture
Vismon: A visual tool for fisheries data analysis	Randall Peterman
Workshop Summary and Closing Remarks	Randall Peterman

Note that the workshop involved considering approaches to uncertainty, risk and stock summaries adopted by selected international fisheries jurisdictions. Those approaches were considered from the point of view of adaptation to the Canadian legal and policy context. Thus, any evaluation of their advantages or disadvantages reported here should be considered in that light, rather than as a review of their suitability for application within the respective jurisdictions.

PART I - UNCERTAINTY AND RISK IN FISHERIES

CONTEXT

Uncertainty and risk are inherent in fisheries systems and thus in decision making about resource use (Rosenberg and Restrepo 1994, Schwaab 2015). Multiple sources of uncertainty can exist in the fisheries science-management system, ranging from the collection of stock and fishery monitoring data right up to institutional processes (Francis and Shotton 1997; see presentation by A.R. Kronlund below). Some examples include:

- The use of fisheries-dependent and independent sample data introduces statistical uncertainty into stock assessments or other management advice. Such uncertainty may also arise from a paucity of information when sampling effort is low or needed data types are missing, leading to so-called “data-poor” cases where quantitative assessments are not possible. (Collectively, these sources are referred to as ‘data uncertainty’.)
- Structural (process) and parameter uncertainties are introduced during the assessment modelling process that can be attributed to the accuracy of assumptions related to the past and future stock and fishery dynamics and the choice of modeling approach (and is also known as ‘model uncertainty’).
- Ecosystem uncertainty relates to unknown, or hard to predict, changes such as directional shifts and system oscillations of various durations and magnitudes.
- Accounting for these sources of uncertainty is part of the scientific component of advice provision, however uncertainty also arises in the application of management actions informed by scientific advice and tradeoffs between conservation and socio-economic considerations.
- Outcome uncertainty relates to whether appropriate limits and targets are being set and is linked to the inherent interdependencies between data, model and ecosystem uncertainties.
- Implementation uncertainty reflects the degree to which adopted management measures are being met; this may vary depending on the quality of monitoring, the performance of

the management strategy in response to underlying changes in stock dynamics, and the behaviour of resource users operating within the management system.

Risk is considered to be the product of both the likelihood and consequence (usually expressed in terms of severity of adverse effect) of an action. Risk assessment or evaluation involves identifying the possible outcome of an action, the probability that each outcome will occur, and the possible consequences (severity) of each outcome. Considering both the likelihood and consequences of an action helps to identify which sources of uncertainty represent the greatest risk to the stock and dependent fisheries. Where risk assessment is conducted, the process may involve one or more of the following steps: estimation of the uncertainty in current stock status, evaluation of the impacts of model assumptions on the perception of status, and projections of future stock status incorporating estimation and process errors to evaluate the expected consequences of different management options. Various trade-offs between expected management outcomes, or utility functions used to rank risk, may be used to inform decisions.

The Precautionary Approach (PA) to capture fisheries (FAO 1995a) acknowledged that changes in fisheries systems are only slowly reversible, difficult to control, and subject to changing environments and human values. The PA involves taking account of uncertainties in fisheries systems, which may not be well understood, and applying prudent foresight to decisions in light of those uncertainties. It specifies the need to identify desirable targets to be achieved and constraints (limits) to be avoided to prevent undesirable outcomes. Such outcomes may include overexploitation, loss of biodiversity, physical disturbances of biotopes, and socio-economic disruptions. Consideration of the inherent uncertainties in fisheries systems is required when developing a management strategy and plan to maintain a low probability that the constraints are violated.

A harvest strategy reflecting the introduction of the PA to capture fisheries was developed for Canadian fisheries in 2006 (DFO 2006) and a policy decision-making framework incorporating the PA strategy followed in 2009 (DFO 2009, “PA Policy”). The PA Policy is a risk management framework for those fisheries under the jurisdiction of DFO. The policy specifies requirements for objectives and decision rules in developing a stock-specific framework, as well as the requirement to take into account uncertainty in the fisheries system.

Resource management decisions under the PA Policy are a form of risk management or mitigation (elaborated in the presentation of J. Marentette below). Scientific input to those decisions requires risk estimation (evaluation) that typically invokes specific assumptions about stock and fishery dynamics. In the absence of stock-specific management objectives, risk estimation may also require assumptions about the choice of constraints and targets guided by legal and policy considerations. In most cases where quantitative fisheries advice is provided, the metric for “risk” is the estimated probability or chance that a particular outcome will occur; whereas actual risk is a function of the probability of an outcome and the consequences of that outcome integrated over time. For the most part, evaluating the consequences of management actions for Canadian fisheries as part of scientific stock assessment has been limited to estimating expected status relative to reference points and anticipated catch. Socio-economic consequences beyond catch and catch volatility are usually not directly integrated into the stock assessment process, nor are cultural consequences. The Canadian PA Policy provides guidance on acceptable tolerance for risk as a function of the probability of (preventable) stock decline conditioned on estimated stock status (see Table 1 of DFO 2009). However, the PA Policy does not articulate standards for managing risk that should be associated with limit and targets such as those established in some international jurisdictions (Marentette and Kronlund 2020).

Fishery scientists can often find it challenging to convert uncertainty into risk and then to communicate risk to decision makers, let alone provide risk estimation in a manner that is equivalent among stocks. This workshop is designed to explore uncertainty and risk evaluation and the communication of risk-based advice in support of resource management decisions. Tools are considered that might be used to facilitate the determination of risks associated with management decisions, as well as means for risk communication.

KEYNOTE ADDRESS

Some considerations about stock/risk assessment, risk communication, and risk management

(Dr. Randall Peterman, Professor Emeritus and Former Canada Research Chair in Fisheries Risk Assessment and Management, Simon Fraser University)

Contemporary fish stock assessments are essentially risk assessments; they take into account at least some uncertainties and their resulting risks. Risk communication and risk management are key elements for appropriate use of information produced by these stock assessments. An important first step in risk communication is to clarify that the term "risk" has two components, (1) consequences or outcomes resulting from uncertain events yet to unfold or uncertain states of nature, and (2) the chance (or probability) of each of those consequences occurring. An event tree that shows these two separate components can help people avoid conflating these two concepts. That problem can also be diminished by banning the use of the phrase "risk of ...", which should be replaced by "chance of ..." to clearly separate probabilities from consequences.

Six sources of uncertainties are essential to consider in fish stock assessments and fisheries management (Figure 1):

1) natural variability in the ecosystem (both high-frequency and low-frequency, i.e., non-stationarity),
2) observation error during collection of data,
3) structural uncertainty about the natural system's true underlying dynamic processes, parameter values, etc.,
4) unclear communication between stock assessment scientists, managers, and stakeholders,
5) unclear management objectives, and
6) outcome uncertainty, which is the difference between a management target and the actual outcome.

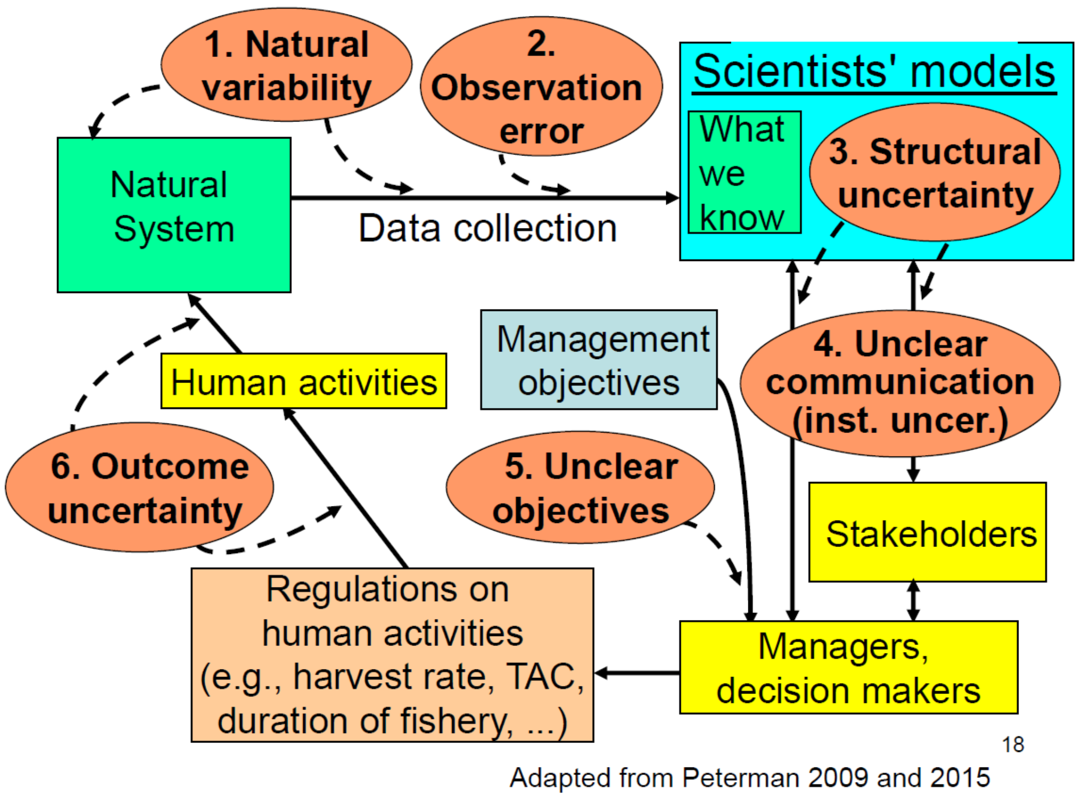

Figure 1. Schematic of the linkages among six sources of uncertainty in a fisheries management system. Adapted from Peterman (2009, 2015).

Dealing with these uncertainties requires different methods. (1) High-frequency, year-to-year natural variability in the ecosystem is easily handled, but low-frequency, i.e., non-stationary processes, such as a gradual reduction in the underlying productivity of a fish stock, requires use of formal statistical time-series methods or state-space modelling. The latter method attempts to separately estimate process variation and high-frequency "noise". (2) Observation error has been included for decades in stock assessment models, and the only suggestion here is to carefully choose the functional form of the variance/error term. (3) Structural uncertainty is usually taken into account by exploring multiple models (even though they might only differ in as little as one equation) rather than developing a single, so-called "best" model. The latter assumes that all other possible models have a probability of occurrence in nature of zero, which is not likely to be the case. Furthermore, traditional statistical methods of finding the model that best fits the data implicitly assume that loss functions are quadratic and symmetric (e.g., mean squared error). However, in reality managers often have asymmetric loss functions in which costs (perceived or real) are larger (or smaller) when outcomes are below a management target instead of above it. With multiple models, extensive sensitivity analyses will show how the rank order of management options and research priorities change across models. Incidentally, more complex models are not necessarily better. At some point as model complexity increases, there is an increasing chance that one or more model assumptions (e.g., parameter values, form of equations) will not only be wrong, but will occur in a critical component that substantially affects the model's output. Morgan and Henrion (1990) aptly state that, "A model should be as simple as possible, but no simpler than necessary".

The fourth category of uncertainties, unclear communication between stock assessment scientists, managers, and stakeholders, is obviously not something that can be modelled, but instead requires other approaches to resolve. A key issue is the complexity and quantitative nature of stock assessments and their estimates of risks (i.e., both probabilities of different outcomes and the magnitudes of those outcomes). These quantitative concepts are not easily understood by many managers and stakeholders, so standard suggestions include, (a) frequent discussions between stock assessment scientists, managers, and stakeholders, (b) training scientists to explain their analyses in less quantitative language, (c) providing science-based workshops for managers and stakeholders to better understand stock assessments, and (d) hiring technically oriented people to serve as the interface between stock assessment scientists and the managers and stakeholders. Fisheries Extension Specialists (funded by the U.S.A. Sea Grant Program) and management biologists may be good examples of the latter approach.

Another key to bridging the communication gap between stock assessment scientists when they talk with managers and stakeholders is for scientists to draw upon research by cognitive psychologists who study how people think about uncertainties and risks. For instance, cumulative probability distributions are better understood when dealing with quantities that have a probability distribution. Also, scientists should be aware that people can interpret the word "probability" in six different ways; only one of these is "chance", which is the meaning that scientists usually intend when talking to managers and stakeholders. To emphasize that "chance" meaning, cognitive psychologists have found that fewer errors of interpretation are made when information is presented in frequency format (e.g., "... in 7 out of 10 situations like this one...") instead of probability format (e.g., "...there is a probability of 0.7 or a 70% chance that such-and-such will occur). Frequency format also helps to reduce the tendency of people to conflate probabilities with consequences when talking about risks. At this workshop, Sean Anderson showed a "Lego plot", a rectangle containing 10 circles, 7 of which would be shaded for this example, which seems like a great way to visually present information in frequency format.

The fifth category of uncertainties, unclear management objectives, is one of the most common yet most difficult issues. Stock assessment scientists need unambiguous, quantitative, operational management objectives that pass a "clarity test" in order to choose output indicators that show how well different contemplated management actions might meet the objectives. Early and frequent communication between scientists and managers will help meet that goal of clarity. However, when managers are still not able to specify quantitative elements of such operational management objectives, stock assessment scientists can conduct extensive sensitivity analyses on alternative sets of those numbers in alternative management objectives to determine how the rank order of management options changes across different objectives.

(6) Outcome uncertainty is perhaps the most important overlooked uncertain component of fish stock/risk assessments. This type of uncertainty reflects the difference between a management target and the actual outcome. It can arise from temporal variation in catchability, harvesters' incomplete compliance with regulations, inappropriate management regulations, over- or underestimates of fish stock biomass, and other factors. Thus, the general term "outcome uncertainty" is preferable to the too-restrictive terms "implementation uncertainty" and "implementation error".

The frequency distribution of differences between management targets and outcomes at the end of a fishing season can be empirically estimated from many years of data. These distributions are often skewed with large variance. When simulations as well as more comprehensive Management Strategy Evaluations have been conducted that explicitly include outcome uncertainty, the effect of that uncertainty is often large enough to overwhelm the effect on output indicators of other uncertainties, including structural uncertainty. Such results will be situation-specific, but they suggest that it is critical to incorporate well-quantified outcome uncertainty into stock assessments.

Risk management within DFO is influenced to some extent by its Precautionary Approach policy, which was adapted in part from the United Nations Food and Agriculture Organization's (FAO's) 1995 "Precautionary Approach to Fisheries: Part 1: Guidelines ...". However, DFO's Precautionary Approach has misinterpreted the intent of the FAO (1995a) guidelines. First, in the widely used DFO graph that shows removal rate, catch, or fishing mortality as a function of stock status (e.g., spawning stock biomass, SSB), the lowest inflection point in the rectilinear function occurs at the Limit Reference Point, which is the boundary between the "Critical zone" and "Cautious zone". However, given the numerous and often large sources of uncertainty described above, that point where catch is reduced to zero as SSB decreases should occur at a SSB greater than the point at which the stock enters the "Critical zone". Similarly, there is no reason why the upper inflection point should occur at the boundary between the "Cautious zone" and "Healthy zone". Instead, the FAO (1995a) guidelines recommend that the shape of the function (and implicitly the location of its inflection points) should be determined by Monte Carlo simulations, preferably whole-system modelling using Management Strategy Evaluation.

ABSTRACTS OF PRESENTATIONS

Risk in Fisheries

Risk in fisheries: Summary of Francis and Shotton (1997) (Rob Kronlund)

After more than 20 years, the view of risk in fisheries by Francis and Shotton (1997) remains relevant in terms of meeting new obligations under the revised *Fisheries Act* and aligning management frameworks with the PA Policy. They distinguish between risk assessment (evaluation) and risk management (mitigation). Science has a significant role in the former activity in providing advice that conveys the possible consequences of uncertainty by illustrating the expected effects of alternate management actions. Risk management relates to the manner in which fishery managers take uncertainty in to account in decision-making. Francis and Shotton (1997) argued that fisheries risk management should result in:

1. Data better used, decision-making more transparent,
2. More strategic planning, fewer *ad hoc* decisions,
3. Focus shifted from annual harvest decisions to the criteria on which those decisions are based,
4. Improved sense of the future of the fishery,
5. Construction of standards against which to evaluate and improve fisheries management, and
6. Meeting desires of scientists for improved advice to fishery managers.

It is not clear, however, that the hoped-for benefits of risk management suggested by Francis and Shotton (1997) have been broadly realized in fisheries. Six categories of uncertainty were defined:

1. Process uncertainty (not “error”, but “natural variability”),
2. Observation uncertainty (measurement and sampling error, misreported catches),
3. Model uncertainty (qualitative and quantitative, incomplete understanding of population dynamics, statistical error structure),
4. Estimation uncertainty (can include types 1-3 above, e.g., retrospective problem),
5. Implementation uncertainty (extent to which intended management is implemented, or management controllability), and

6. Institutional uncertainty (interaction of scientists, managers, resource users in the management process).

Francis and Shotton (1997) noted that institutional uncertainty may be larger than realized and could in fact thwart the intent of recommended management actions (see the keynote address summary in this document for a similar conclusion).

Uncertainty must be carefully articulated to avoid the potential for “burying the lede” of what is known about a fisheries system by emphasizing what is uncertain. Often scientists strive to be honest about their uncertainty in estimating biomass or leading management parameters, or in predicting recruitment. While it is important to note and quantify these uncertainties, it is equally important to emphasize that management options unlikely to perform well have been eliminated from consideration using a process that incorporates known uncertainties that can be quantified. In fact, uncertainty is informative when correctly categorized because it indicates where to invest in data (e.g., categories 2-5) or processes (e.g., categories 5-6) to deal with reducible uncertainties and allows the effects of irreducible uncertainties to be reflected in advice.

Definitions of risk in fisheries vary; the majority of definitions including FAO (1995a) describe uncertainty as the “probability of something undesirable happening”, while some definitions treat risk as expected loss, thus incorporating probability and severity (consequence) of undesirable events. This emphasis on probability may reflect the lack of focus on quantifying risk in form of potential socio-economic losses of a stock collapse if low biomass is not avoided. The difficulty with probability is not a natural metric for many people and decision-makers can be “risk-tolerant” or “risk-averse”. Furthermore, the interpretation of a probability must be carefully described. For example, the risk tolerance for a limit reference point breach might be 95% over 20 years. Does this mean a biomass less than the LRP is acceptable 1 year in 20, or that there must be no more than a 5% chance of a LRP breach in each and every year over 20 years? The latter criterion is far more stringent and management options that met each interpretation independently would provide very different trade-offs in management outcome in terms of average catch and year to year catch variability.

Francis and Shotton (1997) stated that the common view in fisheries was that science does risk assessment and decision-makers do risk management. They cited other views such as Smith (1993) who suggested that roles of scientists are to elicit and clarify objectives, turn objectives into specific attributes and criteria (measurable with matching performance measures), identify a range of strategy choices (management options), evaluate outcomes from applying the options, and communicate the results to decision-makers. Hilborn et al. (1993) stated that there should be two specific limits on scientists: (a) they should make no recommendations and (b) they should not make “best” estimates of biological parameters such as MSY or current stock size (i.e., don’t hide uncertainty by using only a “best” estimate). Rosenberg and Restrepo (1994) disagreed, stating scientists with special knowledge about stocks and models may need to identify a “best” estimate.

Regardless of debate over the role of scientists in fisheries risk assessment, meeting the obligations of the Fish Stocks provisions and providing advice aligned with PA Policy intent means:

- Clarifying and agreeing on risk terminology,
- Clarifying the role of Science in developing objectives (comprising an outcome, probability and time period for evaluation), recommendations, and risk assessment,
- Embracing reducible uncertainties (because they can be resolved, at least in theory) and working to reduce institutional uncertainty,

- Improving narrative skills (don't bury the lede), and
- Focusing on providing advice to inform fishery management decisions intended to avoid bad outcomes, and achieve good outcomes as defined by management objectives.

The PA as a Risk Management Framework

Precaution as Risk Management – Precautionary Approach Frameworks in Canada and Internationally (Julie Marentette)

The precautionary approach (PA) rose to great prominence in the Rio Declaration (United Nations 1992), but the concept originated much earlier in the domains of human health, pollution and the environment. In fisheries, the PA was formally linked to the need to avoid negative outcomes and achieve desirable fishery states in the United Nations Fish Stocks Agreement (United Nations 1995), followed by the FAO (1995b) Code of Conduct and Technical Guidelines (FAO 1995a) where the idea of "long-term sustainable use" as the overriding management objective was first formalized. The common basic principles of the PA include limit and target reference points and management actions that aim to avoid limits while reaching targets on average. Risk management is operationalized in this framework by determining:

a) the set of actions that will achieve acceptable risks of breaching limits and is robust in the face of irreducible uncertainty

b) plans that quantify and reduce other sources of uncertainty.

PA frameworks around the world generally adhere to these principles although each jurisdiction has developed its own set of reference points and terminology. For example, limits to be avoided can vary and might include those associated with overfishing ($F > F_{MSY}$), being overfished ($B < B_{MSY}$), or being recruitment overfished (reproductive impairment or "serious harm"). In Canada's PA Policy (2009), the Upper Stock Reference is a primary tool by which to manage the risk of approaching the limit reference point, although in practice the risks of breaching limits are also affected by uncertainties, the specific configuration of management measures applied to the stock and other acceptable risks (e.g., preventable decline in the short term). PA frameworks in general are also more challenging to operationalize in data-poor stocks, leading to the need to develop data-poor management strategies for stocks around the world that can meet the intent of the PA, even in the absence of clearly defined or reliably estimated reference points.

How Risk is Considered in the ICES precautionary and MSY approaches

How Risk is Considered in the ICES precautionary and MSY approaches (Daniel Ricard)

The International Council for the Exploration of the Sea (ICES) is responsible for the provision of marine science advice in Eastern Atlantic waters. ICES is composed of 20 member countries and relies on an international network of over 4000 scientists. ICES provides both recurring advice and advice in response to special requests. The scientific process leading to the provision of advice is peer-reviewed and evolves in a multi-tier system consisting of expert groups, benchmark panels, advice drafting group and finally by approval by the ICES advice committee (ACOM). For advice related to fishing opportunities, ICES has developed mechanisms to provide recommendations that are based on maximum sustainable yield objectives while also adopting the precautionary approach. The benchmark criterion by which management measures are considered precautionary under the ICES framework is to maintain a stock above its limit reference point with at least 95% probability over an evaluation period. As such, the ICES precautionary and MSY approaches are formulated in a risk-based framework of high relevance to ongoing efforts at Fisheries and Oceans Canada.

DFO Fish Policy Perspectives on Risk Management

Implementation of the Fish Stocks Provisions – Thoughts on Risk and Uncertainty (Marc Clemens and Amy Lebeau)

The new Fish Stocks provisions could mean increased standards for communicating uncertainty and risk by

- Effectively establishing three tiers of binding obligations that creates incentives to document evidence and consistently implement measures to achieve the management objectives,
- Environmental conditions and associated uncertainties must be taken into account under ss 6.1 and 6.2,
- The Minister maintains discretion to consider trade-offs. If exceptions are invoked, the reasons must be published and this may lead to requests to provide the rationale for other decisions and information on economic risks.

The term ‘risk’ is often used in the sense of ‘likelihood’ or ‘probability’. If likelihood and severity of consequences are not separated, this can lead to under-appreciation of low likelihood-high severity events. In fact, the PA Policy states “The appropriate risk to consider when using this framework is the probability of and the severity of the impact from management actions on stock productivity.” Work is therefore needed to develop common definitions of terminology such as likelihood and risk.

Improvements to uncertainty and risk presentation should be investigated for:

- Science advice (e.g., decision tables that report expected outcomes of alternative management choices, decision matrices, or decision trees) and guidance or standards on acceptable risk levels,
- Presentations to stakeholders (e.g., simulation results to show the performance of alternative harvest strategies against objectives, visuals to illustrate risk and uncertainty), and
- In Resource Management recommendations to adopt standard language to show how recommended measures align with the legislative objectives and the PA Policy.

Examples of best practices in the presentation of the potential impact of uncertainty related to environmental conditions on stock status and the implications for management measures would be beneficial for all sectors. The roles of the sectors vary but are complementary in achieving the obligations of the Fish Stock provisions and PA Policy intent:

- Science - develop advice that conveys possible consequences of uncertainty, informed by fishery objectives (risk evaluation),
- Fishery Manager - develop management recommendations that take into account uncertainty and trade-offs among competing objectives (risk mitigation), and
- Decision-makers - make fisheries management decisions that take into account uncertainty and trade-offs (risk mitigation).

The IPCC Approach to Risk

How the IPCC Deals with Risk (Kendra Holt)

The Intergovernmental Panel on Climate Change (IPCC) has developed a calibrated language to communicate uncertainty in key findings presented in their Assessment Reports. This approach is intended to promote consistency among three independent working groups contributing to these reports. The calibrated language, as well as steps that author teams should take to evaluate and communicate uncertainty, are summarized in the *Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties* (Mastrandrea et al. 2010, 2011; hereafter referred to as the 'AR5 Guidance Note').

Within the AR5 guidance note, two metrics are used characterize the degree of uncertainty in key findings. The first of these, *confidence*, is a qualitative metric that communicates the validity of a finding based on available evidence (including the type, amount, quality, and consistency of evidence) and the degree of agreement in the finding among the scientific community. Confidence is scored using the matrix shown in Figure 2. When confidence in assessed as being high or very high, and a probabilistic quantification of uncertainty is possible, the author team proceeds to developing the second, more quantitative metric, *likelihood*. Likelihood is quantified based on statistical analyses of observations, model results, or expert opinion. The calibrated language used to characterize likelihood is shown in Table 3. The AR5 guidance note states that when there is sufficient information, it is preferable to specify the full probability distribution, or a probability range rather than only use terms from Table 3.

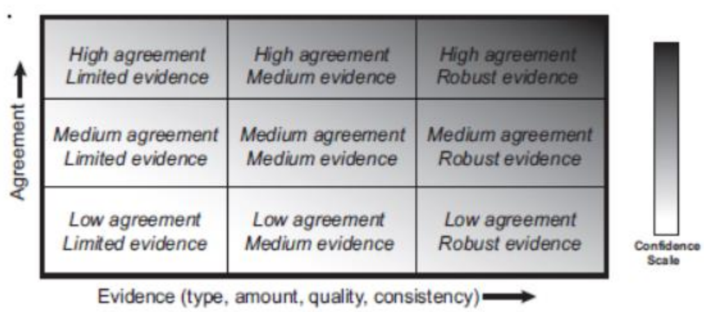

Figure 2. The relationship between evidence, agreement, and the qualitative confidence metric. Note that confidence increases towards the upper right corner, as shown by the increasing strength of shading. Figure is taken from Mastrandrea et al. 2010.

Additional advice provided in the AR5 Guidance Note includes:

1) Provide information on the tails of distributions of key variables when possible,
2) When working in groups to assign uncertainty scores, consider having participants record their scores prior to group discussion to avoid the tendency for groups to converge on a single view and become overly confident, and
3) Consider using reciprocal statements that state both the probability of an outcome occurring and not occurring so that the way a statement is framed does not affect its interpretation.

Table 3. Likelihood terms and scale used to characterize probabilistic measures of uncertainty in the AR5 Guidance Note (Mastrandrea et al. 2010). Additional terms may also be used when appropriate (i.e., extremely likely: 95–100% probability, more likely than not: >50–100% probability, and extremely unlikely: 0–5% probability).

Likelihood Scale	
Term	**Likelihood of Outcome**
Virtually certain	99 - 100% probability
Very likely	90 - 100% probability
Likely	66 - 100% probability
About as likely as not	33 to 66% probability
Unlikely	0 - 33% probability
Very unlikely	0 - 10% probability
Exceptionally unlikely	0 - 1% probability

The AR5 Guidance Note was implemented by all three IPCC working groups for the Fifth Assessment report, which improved standardization among groups compared to the previous four reports. The standardized framework was also considered a useful tool for working through disagreements within working groups. Criticisms of the approach have noted that the flexible relationship between evidence, the degree of agreement, and confidence (Figure 2), combined with the lack of a well-defined scale for the confidence metric, contributes to inconsistencies in reported levels of confidence (Aven and Renn 2015). Additionally, research has shown that that people's interpretation of the IPCC's uncertainty categories can be inconsistent with the intended guidelines, with a tendency to underestimate high probabilities and overestimate low probabilities (Budescu et al. 2009, Budescu et al. 2014). Interpretation improved somewhat when the standardized language was combined with corresponding probability ranges.

The IPCC's approach to standardized likelihood statements has been adapted by Fisheries New Zealand to report on the status of fish stocks relative to biomass-based limits and targets (https://www.mpi.govt.nz/growing-and-harvesting/fisheries/fisheries-management/fish-stock-status). A similar approach could be considered by Fisheries and Oceans Canada for reporting on the status of fish stocks under the DFO Fishery Decision-Making Framework Incorporating the Precautionary Approach.

Risk Equivalency, Buffers and Conditioning Risk

Risk equivalency: what it is, how it works and how it can be used to incorporate climate and ecosystem considerations in science advice for fisheries (Marie-Julie Roux)

Risk equivalency in fisheries is mainly concerned with the application of 'precautionary buffers' to the catch advice in order to equalise risk among assessment types (i.e., data-limited, data-moderate and data-rich assessments). The use of 'buffers' allows jurisdictions to maintain a level of risk consistent with the level considered acceptable to achieve management objectives, given assessment uncertainty. Similarly, 'ecosystem conditioning factors' can be developed and applied to fisheries (catch or effort) advice in order to equalise risk for potential, anticipated and/or observed ecosystem effects. Conditioning factors can be used to quantify the change in risk resulting from ecosystem drivers (risk analysis and communication) and to maintain a level of risk consistent with the level considered acceptable to achieve management objectives, given uncertainty contributed by external, ecosystem state variables (risk management). Ecosystem conditioning factors can be developed and applied across the data richness continuum. This was exemplified in a case study of northern shrimp *Pandalus borealis* in the Estuary and northern Gulf of St-Lawrence, using both a data-moderate (empirical modelling of productivity-dependence on ecosystem variables) and a data-limited method (scoring-based approach using available sensitivity and ecosystem state information, DFO 2020a). Risk equivalency can facilitate the implementation of an ecosystem approach to fisheries.

Insights on Risk in Indigenous Knowledge Systems

Indigenous Knowledge Systems Across Canada: Insights for Understanding Diverse Perspectives on Risk (Steven Alexander)

The incorporation of multiple types of knowledge, such as Indigenous knowledge systems and western science, is an important undertaking, which can strengthen the evidence-base on which policy advice is founded. Furthermore, through the Government of Canada’s commitment to achieving reconciliation with Indigenous peoples, there has been a renewed emphasis on the inclusion and consideration of Indigenous knowledge systems.

The first part of this talk provided a brief introduction to Indigenous knowledge systems and illustrated the interdependent relationship between knowledge, practices, and beliefs through a case study of clam gardening in coastal British Columbia. The second part of the talk then briefly explored how Indigenous ways of knowing and being provide critical insights in relation to risk perceptions. The third part of the talk introduced the *Bridging Indigenous and Science-based Knowledge Web Portal*,a unique web-based knowledge mobilization tool developed by and for DFO Science to access the numerous published studies across Canada’s aquatic ecosystems that integrate and/or include Indigenous knowledge.

Risk Applications 1 – Pacific Salmon

Incorporating risk and uncertainty into science advice for Pacific salmon (Ann-Marie Huang and Carrie Holt)

Science advice is provided for Pacific salmon through a variety of products at multiple spatial scales throughout the fisheries planning and implementation cycle. Products include annual forecasts and in-season estimates of annual return abundances, distribution, and timing; and periodic assessments of status against reference points or biological benchmarks, evaluation of candidate harvest strategies, and the determination of dominant threats and possible mitigation. This advice can be provided at fine-spatial scales (i.e., for Conservation Units, of which there are 460 in Pacific region) to larger scales for stock aggregates. Risk and uncertainty are often accounted for quantitatively in the provision of advice. Forecasts of return abundances are usually provided in probability tables that account for uncertainties in underlying population dynamics. Decision tables provide impacts of harvest decisions on achieving objectives given uncertainties in population dynamics, and closed-loop simulations and management strategy evaluations are used to provide advice on candidate management strategies that more fully account for uncertainties in population dynamics, monitoring, assessment, and implementation of harvest strategies. Multi-indicator approaches are often used to assess status combining information across multiple metrics (e.g., abundances, trends, and spatial distribution) to account for uncertainties and data limitations in any individual metric. Where data to implement quantitative methods are lacking, qualitative approaches can be adopted. For example, ecosystem indicators are provided with the quantitative forecast for Fraser River Sockeye Salmon to adjust expectations based solely on the median of the forecasted return abundances if conditions are expected to be poor (or favourable). In addition, methods to evaluate impacts of additional threats on salmon production have been developed based on structured elicitation of expert opinion (e.g., Risk Assessment Methodology for Salmon, RAMS, and Priority Threat Management, PTM, Hyatt et al. 2017).

Risk Applications 2 – Arctic fisheries and climate change

Incorporating Climate Change into an Arctic Fisheries Risk Assessment Framework (Xinhua Zhu and Ross Tallman)

Climate change in the Arctic has triggered a series of direct and indirect cumulative impacts to aquatic ecosystems. Among those impacts are rising water temperatures, loss of sea ice, melting ice sheets, changes to biological and biogeochemical processes, and extent of Arctic biodiversity. For example, climate change will affect the survival, reproductive development, timing of maturation, and habitat for fish and marine mammals in the Arctic. Specifically, changes in water temperature detected by anadromous salmonids, such as Arctic Char and Dolly Varden, stimulate migration to freshwater and reproduction. Arctic Ringed Seals use ice to rest, pup, and molt. The amount of ice cover affects their movements, ability to forage, reproductive behaviour, and vulnerability to predation. Furthermore, understanding the spatial differences between fisheries, or marine mammal populations, and how they respond to environmental change can inform future management decisions. However, these systems are typically data-limited due to small-scale spatial coverage, small sample sizes, and low reproductive potential. Therefore, the development of an integrated assessment and management framework is critical to be able to account for climate-driven impacts. This assessment will facilitate our understanding of how species' life history parameters shift in concert with changing environmental conditions.

Risk Applications 3 – Groundfish management procedure framework

A management procedure framework for groundfish in British Columbia (Sean C. Anderson, Robyn E. Forrest, Quang C. Huynh, and Elise A. Keppel)

The Pacific Region Groundfish Integrated Fisheries Management Plan lists approximately 80 species-area fish stocks for which annual total allowable catches (TACs) are required in British Columbia (BC). The majority of these fish stocks are considered data-limited, where data-limited stocks are defined as those with insufficient data to reliably estimate stock status or estimate abundance or productivity with conventional stock assessment methods such as statistical catch-at-age models. In recent decades, DFO groundfish stock assessments have focused on data-rich stocks, resulting in a subset of stocks with full stock assessments, while many stocks with less informative data remain unassessed.

The DFO Sustainable Fisheries Framework, legislated via the Fish Stocks provisions in the *Fisheries Act*, requires that fish stocks be managed at sustainable levels or at biomass levels above the Limit Reference Point (LRP). However, for data-limited stocks, data are often insufficient to adequately account for uncertainty in the assessment of stock status relative to biological reference points in the same manner as traditional data-rich stock assessments. In this presentation, we described the approach we were proposing (since accepted at Regional Peer Review, DFO 2021): instead of focusing on the explicit knowledge of current stock status, use a management-oriented approach that emphasizes selecting management procedures (MPs) that have a high likelihood of maintaining fish stocks above implicitly known reference points across multiple plausible states of nature, regardless of the quality and quantity of available data.

We described our methodology for developing appropriate OMs, testing suites of MPs, and identifying MPs that best meet the objectives of fisheries management and stakeholders. We outlined six best-practice steps for MP approaches: (1) defining the decision context, (2) setting objectives and performance metrics, (3) specifying OMs, (4) selecting candidate MPs, (5) conducting closed-loop simulations, and (6) presenting results to evaluate trade-offs. We then described our proposed approach (the "MP Framework") and how it aims to accomplish each of these best-practice steps. The approach makes use of DLMtool (Carruthers and Hordyk 2018) through an ongoing partnership agreement with UBC along with a family of R packages developed by co-authors to facilitate applications of the framework. Included in the framework are provisional conservation and fishery objectives and performance metrics based on Sustainable Fisheries Framework policies, a provisional library of data-limited MPs that are potentially appropriate for BC groundfish stocks, and provisional visualizations to help decision-makers evaluate performance of MPs and trade-offs amongst MPs. Finally, we described a case study of the Rex Sole (*Glyptocephalus zachirus*) stock in the West Coast Vancouver Island groundfish management area to demonstrate an application of the MP Framework. We note that the MP Framework will be applied to an upcoming rebuilding plan for Yelloweye Rockfish (*Sebastes ruberrimus*) in inside waters of Vancouver Island (since accepted at Regional Peer Review, DFO 2020b).

Risk Applications 4 – Risk-based management of scallop fisheries

Risk based advice for the management of Sea Scallop: Experience and challenges from the Maritimes Region (Jessica Sameoto and David Keith)

In the DFO Maritimes Region, Science advice for Sea Scallop is provided annually for 15 management areas; with most of these areas surveyed annually. For each area, advice is derived either from a population model, survey indices, or catch rate indices. For those areas which have a model, a Bayesian state-space biomass dynamic model is fit to survey indices and commercial catch and 1-year projections of commercial biomass are provided. For the 1-year projection, growth and mortality are assumed known and multiple catch level scenarios are presented as "Harvest scenario" tables; it is through these decision tables that risk is communicated. Associated with each catch level, Bayesian posterior medians are used to characterize the expected associated exploitation, the expected percent change in the commercial biomass level from the previous year, the probability that the commercial biomass will increase, the probability of being above the Limit Reference Point, and the probability of being above the Upper Stock Reference. Currently, risk statements or risk categorization language is not employed in the Science advice. In contrast to using models, advice using survey or catch rates indices cannot project ahead and cannot quantify future risk; therefore, future actions are related to the status quo. Further, in areas without reference points, the long-term median of the time series is used to frame current stock status and characterize potential future risk; however, the long-term median is not an explicitly defined fisheries management objective.

Contrasting the three main types of advice:

1. Models - Science confidence in these is relatively high, however stakeholder belief and confidence are variable and often depends on stakeholder experience. The uncertainty and future risk are quantified using harvest scenario tables,
2. Survey indices - Science confidence is generally moderate to high, and stakeholder confidence is variable. Uncertainty in the index is qualified, and future risk is qualified relative to status quo, and

3. Commercial indices - Science confidence in these indicators is relatively low, whereas stakeholder belief can be moderate to high. Uncertainty in the index is qualified, and future risk is qualified relative to status quo.

Additional considerations in relation to characterizing uncertainty and communicating risk:

- stakeholders have differing perceptions and tolerances to risk and this can pose challenges for communication,
- risk tolerance can vary for a species or stock due to the management regime and productivity of the stock, and
- ultimately, what "acceptable" risk tolerance is, is context-dependent, this can pose challenges for standardization.

Black Swans and Risk-Based Advice

Black Swans and Do We Need to Consider them in Risk-based Advice and Management (Sean C. Anderson)

Black swans are highly improbable events with major consequences that are often only considered predictable in retrospect. Such events define the world around us—from banking collapses to earthquakes. In fisheries, black-swan events could refer, for example, to abrupt declines in fish abundance or massive recruitment events. In this presentation, I considered how we can integrate the concept into fisheries science. I explored why we would expect black-swan events fisheries: marine ecosystems contain a large number of non-linear interactions, humans magnify the consequences of abrupt changes in marine ecosystems and fisheries, and it is easy to place too much faith in the complex models we use to assess them. I then summarized evidence for black-swan events being a regular feature of fish populations. I suggested four main challenges and associated solutions related to black-swan events in fish and fisheries: (1) try to avoid surprise through improved understanding of ecological and fisheries systems; (2) embed surprise into assessment models through approaches such as heavy-tailed distributions; (3) make systems robust to surprise through approaches such as integrating extreme events into closed-loop simulations, choosing adequate uncertainty buffers around reference points, and promoting permit diversification among fishers; and (4) detect and react quickly to surprise through broad monitoring, automated data visualization, and institutional preparedness.

Fish Stocks Provisions and the Record of Evidence

Fish Stocks provisions and the Record of Evidence (Amy Lebeau)

The Fish Stocks provisions (FSPs) were introduced as part of the amendments to the *Fisheries Act* in June 2019 (sections 6.1—6.3). They strengthen DFO's fisheries management framework by establishing binding obligations on DFO to manage prescribed major fish stocks at levels necessary to promote their sustainability, taking into account the biology of the stock and the environmental conditions affecting the stock. If a prescribed stock declines to or below its Limit Reference Point (LRP), a rebuilding plan must be developed and implemented. These FSPs are based on DFO's 2009 Precautionary Approach Policy, and thus the policy provides guidance on how to meet the new obligations. Further guidance is also in development.

To support the implementation of the FSPs, DFO is developing regulations to (a) prescribe the first "batch" of major stocks subject to the FSPs, and (b) set out the required contents and timelines to develop rebuilding plans. The required contents are based on DFO's 2013 Rebuilding Guidance. In addition, the proposed regulations would require plans to be completed within 24-months of the stock declining to its LRP (with an optional extension of up to 12 additional months). The Rebuilding Guidance is under revision to align its contents with the new legislation and proposed regulation.

The FSPs establish a higher standard for accountability and transparency. There will likely be requests for information about management decisions made for prescribed stocks as well as applications for judicial review. To proactively prepare for such requests, National Fisheries Policy is recommending that the evidence of how DFO has met the obligations for each decision be documented in (a) the decision memorandum, and (b) a record of evidence (RoE). The RoE is intended to function as an annotated bibliography of the full management cycle including the advice and analyses that contributed to the management recommendation, the management recommendation itself, the decision made by the Minister (or delegated authority), and an outline of how the decision was implemented.

Collaborative Tools for Generation of Standardized Documents

Modern collaborative tools for automatically generating standardized documents (Andrew Edwards and Sean C. Anderson)

Modern computational tools allow efficient generation of scientific documents by teams of analysts. The programming language R (R Core Team 2019) is widely used in DFO for making calculations and generating figures for stock assessments. The R package RMarkdown is used to generate dynamic reports from the calculations. Git and GitHub allow collaborators to easily share and update their code. Two recent examples from Pacific Region are the annual Pacific Hake (*Merluccius productus*) stock assessment and the GFSynopsis report (Anderson et al. 2019) that provides visualizations of data on 113 species of groundfish in British Columbia. Advantages of using the modern tools are reproducibility, efficiency (given the short time between receiving Pacific Hake data and submitting the assessment, and the need to generate the same figures for all 113 species of groundfish), and consistency (the Pacific Hake advice is presented in a consistent manner from year to year, and the groundfish data are consistent between species).

The key to dynamic report generation is that instead of writing "The probability of being in the healthy zone is 0.75", the analyst has code that says "The probability of being in the healthy zone is `r prob.healthy`". The R variable 'prob.healthy' is the result of model calculations in R, but when the calculations are updated (say, with new data) and the value of 'prob.healthy' changes, the text will automatically be updated and be correct. This concept extends to figures and tables. Such automatic generation avoids time-consuming and error-prone manual copy-and-pasting.

There are advantages to adopting a similar approach for stock summaries. For example, summaries based on a word processing template are not traceable or reproducible, inefficient, error-prone, and can have variable formatting. In contrast, an R-package could include functions that read in data and model results, automatically produce a consistently formatted stock summary document (e.g., PDF) of standardized text, figures and tables. In addition, creation of both the English and French versions can be automated. Development of the package could be accomplished in a series of steps:

1. Scoping
    - Essential information,
    - Consistent layout,

- Standard text, figures and tables,
- Options for different formats for various contexts and audiences (e.g., species types?),
- Feedback from potential users.

2. Software - Based on concepts and packages established from previous examples and at the TESA TTT workshop on tools for Transparent, Traceable and Transferable assessments (see here), a small team to develop:
   - GitHub to share code and collaborate,
   - R package to support data manipulation, tabular summaries and figures,
   - RMarkdown for producing the stock summary.
3. Standardising - analysts would need to translate results into a standard format, but no need to standardize modelling software or model choice.

BREAKOUT EXERCISES 1-4

Exercise 1: Topics in Risk and Uncertainty

Five groups were formed for Breakout Exercise #1 with each group assigned a topic from (Table 4). Each group was asked to provide the following deliverables for their topic:

- A description of how the breakout exercise topic was interpreted by the group,
- A summary of what was discussed,
- Solutions, recommendations, and ideas,
- Short- and long-term implications of considering the topic, and
- The top two key points on the topic.

Table 4. Topics for breakout exercise #1.

Number	Exercise Topic
1	*The other part of risk*: consideration of consequence is part of the analysis. Cost-benefit analysis is part of this step. Consider how, and when. we might consider consequences outside the PA, including ideas about qualitative and quantitative risk analysis.
2	*Management Strategy Evaluation (MSE) vs other paradigms in consideration of risk*: Note that ICES has a separate stock category for MSE. This is really because MSE incorporates risk assessment. Given parameters (objectives and performance) for managing risk, the MSE approach tests the relative performance of risk management strategies. Explore these ideas further and keep in mind how to address the obligations of the Fish Stocks provisions that include the need for a LRP.
3	*What are we missing from other fields?* Risk ideas in fisheries may not be as developed compared to other fields such as actuarial science, human health and safety; all of these fields have more money and more researchers than fisheries. What elements in these fields are missing from fisheries? What concepts, methods for assessment, presentation styles should we consider?

Number	Exercise Topic
4	*Applications of Ecological Risk Assessment for the Effects of Fishing (ERAEF, Hobday et al 2011)*: ERAEF is the Australian system for creating risk assessments from the qualitative to the quantitative. ERAEF has been applied with mixed success including in Pacific groundfish (partially; Holt et al. 2012). What are the strengths and weaknesses and how might we apply it in Canada, considering scientific capacity, data, regions, sectors, time-frames. Also consider operational steps that would be required.
E1.1 (Bonus)	*Developing parameters for case-study examples*: Most of us find that worked examples are one of the best ways to understand the concepts and the range of applicability of the concepts. Based on Workshop Day 1 ideas, what are the parameters for case studies to develop, i.e., what is the range of case studies that should be considered to encompass most of our problems. Consider data richness, biological knowledge, and the resource user environment. Consider the use of case studies as a reference set, which could be analogous to a reference collection for otoliths. Think of the case studies that will be developed as something that others can review to determine what may be required for their own situation.

Topic 1: The other part of risk: consequences

The group discussed the definition of 'consequence' for fisheries, assuming that the cost is to the fishery and noting that the timeframe over which consequences are evaluated is important to consider. For example, decision-makers must weigh trade-offs between short-term economic changes (desired or undesired) that result from management actions against the biological impacts of such decisions may be delayed or experienced over longer periods. As an example of this, short-term economic impacts may lead to improved long-term biological as well as economic benefits (e.g., rebuilding fish stocks). The group debated whether socio-economic costs should be considered in the stock assessment, concluding that a socio-economic analysis might be needed to meet the obligations of the Fish Stocks provisions. However, it was suggested that roles and responsibilities needed to be well defined for the different sectors contributing to advice. The idea of assessment outputs including the effect of a minimum threshold of economic viability was suggested as a means of demonstrating trade-off consequences, in addition to constraints represented by conservation objectives.

The provision of cost-benefit analyses of biological consequences as a role for science was discussed. For example, high density of Sea Urchin in the Pacific leads to decimation of kelp forests which has a negative impact on those species that use kelp as cover and foraging areas. At the same time, high urchin density has a negative effect on the Sea Urchin gonad fishery since gonad development is reduced at high densities. The group concluded that this type of trade-off problem should be considered in multi-species (ecosystem) assessments rather than traditional single-species assessments.

The main recommendation from the group was to evaluate and apply a qualitative risk assessment tool in addition to, or in lieu of, quantitative risk assessment. For example, NOAA has adopted qualitative risk tables (Dorn et al. 2020) to develop buffers for the following five categories: ecological, economic, social, food production/security, and management. The categories are designed to be used in an open and transparent decision-making process. The group suggested that an additional "cultural/rights" category should be added to increase alignment with the obligations of the revised *Fisheries Act*.

Topic 2: Congruence and differences between how Management Strategy Evaluation (MSE) deals with risk and the standard paradigms for dealing with risk.

Experience with MSE among group members varied widely from basic familiarity with the process to experience with MSE in fisheries applications. A comparison of the attributes of MSE and traditional risk estimation in stock assessments was compiled.

Table 5. Comparison of MSE with traditional stock assessment risk estimation.

MSE	Traditional Stock Assessment
Risk discussions happen earlier in process.	Risk often estimated using a decision table as an output of the stock assessment.
Risk discussions are “baked into the process”, with end user groups involved from the onset.	End user groups deal with risk after stock assessment process is completed separately from the science activities.
More transparent.	Risk estimation typically related to breaching limit reference points, likelihood of population increase or decrease.
Early risk discussions can result in better, more clearly articulated objectives that specify risk tolerances.	Choice of risk depends on end user comfort level after the risk estimation step.
Some end users may have the perception that MSE will result in loss of control in a decision-making process. Improved communication and experience with the MSE process can help alleviate that concern.	No feedback to Science after decision is made.
Can fail if there is no framework in place to operationalize the results of the MSE. Also it is unclear when an MSE should be undertaken or an alternative process applied.	Decision-making may not be repeatable in that risk tolerances can vary over time and according to the individual risk aversion of decision-makers.
Precaution can be built into the MSE process by virtue of defining objectives and evaluating trade-offs in management outcomes.	No pre-set structure or requirement for science communication with stakeholders outside of the formal CSAS peer-review process.

The group noted that MSE is not required to meet science advice provision needs for all stocks. The issue was raised as to whether a single limit reference point had to be estimated within an MSE since each hypotheses regarding stock and fishery dynamics is characterized by its own set of reference points. This arose because the premise of the MSE approach is that a management procedure is sought that is robust to the consequences of a range of uncertain stock and fishery dynamics, and is not vulnerable to any one set of assumptions about the dynamics being true as in the case of the single “best assessment” approach characteristic of traditional stock assessments.

The group provided several recommendations to support the application of MSE and contrast it with traditional single-best-model stock assessment:

- Develop a briefing package describing the MSE process, how MSE relates to PA Policy implementation, where resource users have input to the process and the nature of the fisheries management decision.
- Develop a briefing package on how the MSE process differs from traditional stock assessment and identify how each approach compares with respect to the six types of uncertainty identified by Francis and Shotton (1997).
- Develop a description of how reference points are embedded in the MSE process and how the obligations of the Fish Stocks provisions and PA Policy can be met without a requirement to estimate a single LRP, and
- Develop standardized text that describes how stock status estimation is conducted within the closed-loop simulation methods used to support a MSE process.

Topic 3: What are we missing from other fields?

The group considered the need for client identification and whether a risk-based approach is needed for a given client with respect to the questions asked of fishery scientists. High consequence fields with feedback are likely to be the most relevant to fisheries science for learning: insurance and actuarial fields, airlines, health care (hospital management, epidemiology), food safety and inspection, nuclear and petro-chemical industries, and military. In those fields risk assessment may be applicable to individuals in many cases, but also populations (e.g., epidemiology). The group noted that the social sciences may provide insight into resolving challenges related to working with various client sectors and developing qualitative approaches where necessary.

In terms of learning from other fields, the group noted the following items:

- Breakdown of concepts (e.g., hazards, mitigation): strong institutional drivers to ensure strict product definitions and what must be delivered,
- Use of qualitative approaches: other fields often focus on what information is available rather than what information is lacking using weight-of-evidence approaches (e.g., Tao et al. 2018),
- Frame consequences of fisheries management decisions in terms of cost, such as loss of jobs, change in sustainability of the stock,
- Expand a linear/narrow view of fisheries to consider multiple system components and consequences that are well explored beyond the catch outcome (e.g., approach used in hospitals),
- Consider timescale in outcomes, e.g., consequences 10 years into the future rather than one year ahead, and clearly articulate the nature of those consequences,
- Present a full spectrum of outcomes in advance of consultations or decision-point to managers,
- Develop and establish a hierarchy of objectives and assessment of outcomes based on different risk tolerance levels,

- Recognize a significant part of the decision-making process is external to science activities, e.g., socio-economic risk estimation. Outcomes may be affected by institutional uncertainty.
- Examine different scenarios of economic quantification and consequences. In other fields, economic analysis is peer-reviewed but is not usually reviewed in fisheries contexts.

In terms of steps to improve the risk estimation and management process, the group recommended:

- Ideally, all participants would be involved in the entire advice-to-decision cycle in a more comprehensive manner,
- Add redundancy (e.g., in commercial jet travel there are 2 engines, 2 pilots, etc.). In fisheries this might take the form of more than one group doing or reviewing the assessment,
- Consider a “bow tie” approach: Develop a checklist of pre-agreed-upon steps that include routine measures to be taken to avoid a ‘bad event’ and measures to be taken when a ‘bad event’ occurs, despite efforts to prevent one. Include tools to evaluate in a semi-quantitative manner how effective the measures were at avoiding or minimizing negative effects,
- Practice for various situations (e.g., pilots practice with flight simulators). Trial (e.g., using simulations) mock fisheries that engage the whole data-to-decision system, i.e., if a stock assessment indicates a given outcome, what actions do decision-makers take?
- Institute software testing including a reproducibility requirement so that results can be duplicated independently,
- CSAS considerations:
    - Include the requirement for risk-based advice in Terms of Reference, tailored to the client and their question(s).
    - Include the need to show trade-offs that include socio-economic outcomes in forecasts or simulations.

The group determined there was short-term value in collecting and evaluating information, and in engaging experts, from other fields but noted that implementation of risk concepts from other fields may be challenging over the long-term. In addition, it was recommended that experts from other fields be engaged in fisheries science activities to introduce multi-disciplinary considerations into the “advice to decision” process.

Topic 4: Ecological Risk Assessment for the Effects of Fishing (ERAEF)

The group considered the ERAEF approach for creating risk assessments and considered the advantages and challenges of operationalizing ERAEF in a Canadian context. A Pacific groundfish pilot study was discussed to provide an example (Holt et al. 2012). That study was presented to fishery managers, but the focus in the region studied remains on single species approaches rather than the broader ecosystem considerations involved in conducting ERAEF. The group agreed the ERAEF approach as potentially beneficial for fisheries decision-making but noted considerable investment of resources would be required for implementation. The process is intended to be applied at an ecosystem scale, capturing stressors such as capture fisheries on target and non-target species, vessel noise, oil or other contaminants, etc. The approach takes a triage approach to rank risk, beginning with qualitative ranking at level 1, semi-quantitative at level 2, and quantitative at level 3 in the form of stock assessment, or MSE.

Potential advantages of applying ERAEF identified by the group included:

- Would enable the department to triage a large workload with the potential to identify high risk activities or stocks currently at risk,
- Could be used for prioritization of species for recovery planning and MSE processes,
- Although designed for ecosystem-level application, there is potential to apply to the principles and steps at a species-specific level, and
- Could be adapted to simplify steps to an incremental approach such as looking at one threat (e.g., fishing) and focusing on specific species or assemblages of species.

However, application of ERAEF is challenged by the following considerations:

- ERAEF requires buy-in from all sectors in the decision-making process,
- Broad expertise from many scientific disciplines is needed such as climate change, oceanography, ocean contaminant and marine mammal specialists, etc.,
- ERAEF could be vulnerable to cognitive bias of group conducting the qualitative scoring steps,
- The approach is limited to ecological risk and does not include socio-economic or cultural factors in the triage.

In order to apply this in Canada, the Science Sector would need clear direction and multi-sector support. It was concluded that review of ERAEF application in other jurisdictions would be helpful to determine the utility for Canada. Although incremental steps were advised, the group suggested that ERAEF could help operationalize Ecosystem-based Fisheries Management but would require adequate resources and support.

Topic E1.1: Developing Parameters for Case Studies

The group determined that *example cases* (rather than deliberately-performed case studies) of useful risk analyses should be provided, assuming that the cases led to clear support for fishery management decision making. Suggestions included:

- Example cases should be risk assessments that were *actually* conducted; and subsequently used to make management decision(s) rather than theoretical cases. Implicitly, the results of the management decisions could be assessed against the *a priori* risk analysis. Examples where quantified management options based on risk categories would be most useful (e.g., decision table provided along with specified management options).
- The user could compare the risk management options with *actual* management outcomes (e.g., target for escapements compared with actual management outcomes).
- Examples should be sought from international best practices for risk assessment.
- Emphasize simplicity in both the choice of risk assessment paradigm and methodology as much as possible.

- Necessary to ensure the examples include *both* probability and consequence where available (e.g., consideration of implications of “serious harm” to the stock and dependent fisheries).
- Includes examples of qualitative and quantitative risk assessments.
- Choose divergent or polarized case examples. For example, it would be useful to juxtapose low risk and high consequence vs. high risk and low consequence cases as per the IPCC matrix (Mastandrea et al. 2010).
- In the choice of example cases, it will be important to identify the target audience (e.g., fishery managers, scientists, stakeholders, First Nations, public).

Key issues identified by the group included:

- The risk assessment should ensure fundamental knowledge and characterization of:
    - Spatial and temporal distribution of fisheries,
    - Life history parameters (biological characteristics),
    - Environments (environmental regimes).
- Different fisheries management systems and regimes (e.g., input vs. output controls),
- Scale of fisheries (number of resource users, size of catches, spatial distribution),
- Conveying ‘value’ of the risk analysis (e.g., ecosystem, financial, social, etc.),
- Choice and import of iconic species (e.g., salmon),
- Lessons learned from existing fisheries (e.g., Atlantic cod),
- Operationally useful for effective communications (e.g., marine mammals),
- Black-swan events (unpredictable extreme events),
- Inclusions of socio-economic and cultural information and trade-offs where available,
- Land claim issues (legal, constitutional challenges),
- Decision tree (for selection of risk assessment methodologies),
- Historical inertia (how risk assessment is introduced to a fishery context, stakeholder expectations, etc.).
- Matching resource user and community expectations to management measures (e.g., approaches needed for Arctic communities where traditional management measures may not be feasible),
- Risk tolerance of the various participants in the fisheries management system,
- May be useful to develop a system map as a communication tool to illustrate connections among the values being assessed (e.g., spatial, time, resources),
- Variety of communication methods for how risk should be portrayed (e.g., 70% chance of being above LRP; vs. 3 out of 10 years the fishery will be closed).

The group identified criteria for the selection of example cases. Example cases should include iconic or keystone species, a range of management systems, both data-poor and data-rich examples, and a variety of species and life history characteristics (e.g., salmonids, groundfishes, invertebrates, small and large pelagics, and short- and long-lived species). The long-term implications of a standardized, common set of risk assessment examples were considered to be beneficial to encouraging consistent provision of risk-based advice. There was concurrence that DFO Science should develop:

1. a *common set of risk definitions* (a glossary) as an essential first step. These definitions (including quantitative ranges for each definition or category) could be provided via a Science guidance document. For example, the term “data limited” is often used to describe the amount of data available for a fish stock, but there is no common interpretation for what is encompassed within this terminology.
2. a *decision tree* to guide analysts as to the choice of available risk assessment tools appropriate for specific situations. For example, certain risk assessment methodologies may be best suited to certain species, environments, or data availability situations.

Exercise 2: Communication of Risk and Data-Poverty

Five groups were formed for Breakout Exercise #2 with each group assigned a topic from Table 6. Each group was asked to provide the following deliverables for their topic:

- A description of how the breakout exercise topic was interpreted by the group,
- A summary of what was discussed,
- Solutions, recommendations, and ideas,
- Short and long term implications of considering the topic, and
- The top two key points on the topic.

Table 6. Topics for breakout exercise #2.

Number	Exercise Topic
5	*Comparative risk levels group*: look in ICES, New Zealand, Canada, elsewhere and develop an example of risk levels that would be compatible with international norms for various well-known processes. A proposal for DFO.
6	*IPCC risk language group*: develop a language set that communicates risk levels useable in fisheries. Propose recommendations on levels and how to present them combined. Also discuss some of the communication issues with this (follow the deliverable guidelines), e.g., what would we achieve with this? Draw upon examples from these jurisdictions and areas for support.
7	*Risk communication tools, language*: try out examples in terms of tables, figures, language, frequency vs probability and what each means. If you have names of plot/table types for this kind of communication write these down. Consider all downstream uses and audiences.
8	*Risk evaluation over the data and knowledge continuum:* Consider the multiple model paradigm, MSE. qualitative and quantitative models: confidence vs likelihood.
E2.A (Bonus)	Ecosystem, climate and bringing in other information in risk: how do we consider risk when other factors are affecting stock and when those factors are changing. Consider random variation, directionality, regime-like behaviour, non-linearity and thresholds. What are the methods that could be considered, examples from Canada and elsewhere?

Topics 5 and 6: Intergovernmental Panel on Climate Change (IPCC) risk language and comparison between risk levels of ICES, NZ, Canada and others.

Topics 5 and 6 were combined with the additional instructions to develop a language set that communicates risk levels suitable for a fisheries context. Draw upon examples from comparative jurisdictions and areas for support.

The group compared two documents: the IPCC report and the report that compares risk levels used by various countries and Regional Fisheries Management Organizations. The group discussed the various approaches used and identified advantages and challenges to each approach.

- It was thought people misinterpret negative phrasing more than positive phrasing. The group decided it is cumbersome to try to use both positive and negative approaches when describing level of risk and for clarity of message, one should use just one approach consistently and probably positive phrasing.

- Phraseology should be consistent across stocks and regions (e.g., consistent reporting of the probability of being above the LRP).
- The IPCC risk language table uses a likelihood scale. The scale is citable, easy to understand and based on cumulative probabilities. The middle category of ‘as likely as not’ is quite broad at 33-66%. It was recommended that the international standard provided by the IPCC risk table should be adopted in DFO fisheries. The IPCC risk table has already been adopted in other jurisdictions (e.g., modified for application by New Zealand).
- In comparing risk levels across jurisdictions: ICES was most stringent of the jurisdictions examined. ICES’ acceptable risk of a 95% chance of staying above limit reference point in each and every year was thought to be unrealistic for use in the Canadian context.
- Risk tolerance in the Canadian PA Policy is expressed in terms of trends (i.e., risks of decline) as opposed to risks of breaching limits.

It is recommended that IPCC risk language table (IPCC 2010) could be incorporated into the DFO Precautionary Approach Policy and Fish Stocks provision guidance. A CSAS advisory process would be needed to have this adopted reporting in products such as Science Advisory Reports (SARs) or the Sustainability Survey for Fisheries (DFO 2018a) with defined standards for application.

Topic 7: Risk Communication Tools

The tools used for risk communication will depend on the audience. Typically, DFO Science is required to communicate risk concepts to Fisheries Management, the Oceans and Habitat sectors, Indigenous groups, land claim boards, community groups, commercial fishers and commercial fishing organizations, recreational fishers and groups, the media and the public at large.

Main challenges include language (French, English, Indigenous), education of the audience which includes establishing vocabulary and an appropriate technical level, and the potential for different interpretations of risk between groups.

- Frequencies are often better understood that probabilities over a wider audience,
- Cumulative distributions can be useful for more knowledgeable audiences,
- Confidence intervals could be presented graphically with shading that included fading edges at more extreme probabilities in order to better characterize improbable but high consequence events,
- Colour schemes for presenting uncertainty and risk now have a number of tools available such as the “colourbrewer” and “viridis” packages in R (R Core Team 2019). It is important to consider colour blindness for graphical communication,
- Visual presentation of risk should consider the “information/ink ratio,” with larger values being better but the complexity of the information must be sufficiently captured by the plot,
- One should consider that “common look and feel” layouts build familiarity.

Main recommendation:

DFO would benefit from a process to develop a guidance document on risk communication and include templates where possible.

Topic 8: Evaluating risk over the data-richness continuum

- Many jurisdictions already develop advice and communication organized along a data richness classification. DFO would benefit from a similar classification scheme,
- Data limitation may mean that a quantitative likelihood evaluation cannot be conducted but there is still a level of confidence in existing evidence, such that management advice directions may still be clear. That is, data limitation is not necessarily a limitation on providing useful advice.

Recommendations:

- DFO should consider developing a tiered system for stock assessments based on data availability, with assessment and risk tools that are customized to each tier category (e.g., ICES).
- Develop a set of worked case studies that encompass a range of data-richness as an information tool and communication tool for analysts.

Topic E2.A: Considering risk in fisheries advice with external factors

This breakout group considered qualitative and quantitative methods for including ecosystem variables (EVs) and provided a range of potential methods rather than simply assessing the value of including versus not including ecosystem variables.

Requirements to include Ecosystem Variables: From the Pacific region’s perspective, there should be a section about ecosystem considerations in Research Documents and SARs. Generally, per DFO 2019, environmental considerations have not been included in the final advice recommendations.

The group’s experience was that management decisions tend to be based on long-term averages or medians. However, variance in environmental conditions is increasing; the range of possible outcomes implied by increased system uncertainty should be taken into account in both science advice and management decisions.

Management Strategy Evaluation (MSE) was suggested as a possible method for better incorporating increasing variance/uncertainty in analyses of stock status and trends.

Quantitative considerations:

1. Shift the distribution (ACCASP review),
2. Modeling approach using MSE, adjusting input parameters in the operating model, or changing structural assumptions in operating models to account for variability/change,
3. Sample from the tails of the distribution.

Qualitative considerations:

1. Use of conceptual models,
2. Expert judgment - especially weight-of-evidence approaches. What constitutes an acceptable standard of expert opinion? Can a minimum standard be defined (e.g., is one expert sufficient)?
3. Use of the comparative approach, looking at analogous situations (e.g., small pelagics or salmonids, or stocks with similar life histories).

Specific examples discussed:

- Multi-species scenarios: shrimp/cod/snow crab/capelin,
- Northern abalone (e.g., -a case study in Pacific Region, where adding sea otter occupancy time was noted to have improved the predictability of the model, may be a useful case study for the EAFM WG (points of contact: Shannon Obradovich and Christine Hansen). ,
- Species distribution modeling/occupancy models,
- MSE: allows assessors to include a range of temperatures, or time-varying mortality (e.g., Pacific Herring),
- EAFM WG case studies should be moving beyond just the correlation of variables, into an understanding of the variability of these ecosystems,
- Australia: suggestion to examine potential approaches used to deal with Great Barrier Reef (GBR) warming events,
- Fisheries Management in the Bering Sea: the use of broad ecosystem principles in the stock assessment process (e.g., a cap applied to Total Allowable Catch (TAC) for the Bering Sea). For instance, it has been reported that there are maximum TACs that have been established at the ecosystem level (e.g. 2 million tons; Knapp et al. 2015), with a prescribed allocation scheme therein.

The group noted that there are few examples where ecosystem variables have been explicitly included in fisheries advice, and not many examples of including it when the climate change information has not been validated (Pepin et al. 2020).

Difficulties:

- It is important to consider the likely consequence and the likely effects of non-stationary environments (direction and magnitude of environmental change). The group discussed the viability of inclusion of unpredictability, severity, likelihood of persistence of these environmental changes.
- It was suggested that in many ecosystems, researchers should be able to identify most important environmental drivers (e.g., changes in water temperature, a major contributor to uncertainty and risk as a result of climate change), but that in many instances, the consequences of environmental change on the directionality of stock response is unknown.
- It was noted that researchers have the ability to use risk-based or environmental assessment approaches: including important environmental/climatic indicators such as magnitude, scale and direction of effects (based on best available information), but it was recognized that within fisheries agencies there may be a hesitation to adopt or move forward with novel approaches vs. traditional methods (e.g., institutional inertia).
- There was discussion about consideration of terrestrial examples. Would it be beneficial to consider ‘lessons learned’ from non-aquatic species to provide potential approaches for the incorporation of EVs into fisheries population models?
- For DFO, there are scenarios which are data-limited, or resource-limited such that there are insufficient resources to analyse existing data. Basic scientific research is still needed in the Department despite an increased focus on carrying out applied research.

For example, there remains significant knowledge gaps regarding the fundamental life history parameters for many stocks/species.

- It was noted that many fish stocks are starting to encounter more frequent extreme events, and lack of understanding on how to deal with these extreme events is a challenge to ensuring sustainable fisheries (e.g., many of the recent forecasts of Pacific salmon returns have been higher or lower than expected).
- Time-varying reference points: non-stationarity was acknowledged as an important challenge but to date, there are few examples internationally of jurisdictional guidance on this issue.

Solutions, recommendations, ideas:

It was suggested that stock assessments/population models compare/contrast the incorporation of environmental variables (vs. a base case that excludes EVs), and thus compare the simulation-based outcomes of both hypotheses.

Short- and long-term implications of considering this topic.

It was noted that it would be easier to include information on short term changes in EVs (e.g., sea surface temperature (SST) for the year), than it would be to include long term projections based on EVs. Importantly, there is insufficient information about the underlying environmental mechanisms to provide strategic advice on EVs based on those mechanisms, suggesting that strategic advice would need to come from alternative avenues based on consequences to management outcomes.

Key points coming out of the discussion:

- To date, the inclusion of environmental variables has largely examined historic trends in fisheries responses, and has seldom been predictive in nature (i.e., future states). Efforts should be made to develop new methods and/or change historic ways of presenting science advice (i.e., use of risk-based advice derived from analysis of future stock prognoses over a range of possible conditions).
- Both the risks and benefits of directly including environmental variables in stock assessments should be evaluated using MSE/closed-loop simulation methods.

Exercise 3: Case Study

For Exercise 3, breakout groups developed mock Science Advisory Reports that included risk-based advice (Table 7).

Table 7. Description of breakout exercise #3.

Case Study:	Southern Gulf of St. Lawrence Turbot. Derive useful risk-based advice (or outline the steps required to develop this risk-based advice)
Materials:	One dataset per group will be provided. This data set may be used directly or indirectly. Data sets will range from data rich to data limited in terms of stock and fishery monitoring and life history information
Task:	Develop risk-based advice (or outline the steps required to develop risk-based advice) for use by decision-makers based on the information, given data and knowledge availability differences.

Case Study:	Southern Gulf of St. Lawrence Turbot. Derive useful risk-based advice (or outline the steps required to develop this risk-based advice)
Consider:	1) Reference point development 2) Uncertainty and probability 3) Plausible management actions 4) Acceptable risk levels 5) Costs and benefits of various actions 6) How to communicate uncertainty and risk to decision-makers
Deliverable:	Detailed written report to discuss in plenary that could include examples of the following to help a manager make risk-based decisions: • Graphics • Tables • Advice options with statements that capture risk. Given the limited amount of time, it may only be possible to outline steps in how the development of risk-based advice would occur for this hypothetical example, rather than providing a worked case study.

Some groups fit models to data to complete the exercise. Although the data were derived from a real stock, the exercise was done for the purposes of considering risk practices and results are not intended for consideration as advice.

Overall, the approaches explored some data limited techniques that had recently been taught at an ICES data limited methods course. A production model was also fit in one case to aggregated data that had no length composition. A data limited case that looked at surplus production in coordination with an environmental variable was also tried. These exercises allowed assessment biologists to practice using risk-based advice and employ some of the visualisation techniques and procedures developed by IPCC.

Exercise 4: Roadmap for risk-based advice

For Exercise 4, breakout groups works to draft a roadmap that would enable DFO Science to more readily provide risk-based advice (Table 8).

Table 8. Description of breakout exercise #4.

Breakout exercise #4: Roadmap for the development of risk-based advice by DFO Science	
Task:	Given what you've learned in this workshop so far, outline the roadmap required for the development of risk-based advice by DFO Science.
Consider:	Who, what, when, why for major tasks, activities, meetings, etc. that need to occur.

Processes or working groups could be developed to:

- Provide improved specification/understanding of the IPCC framework regarding confidence/likelihood application including a list of standardized terminology and guidance on how to use it,

- Develop clearer specification of what risk means and associated terminology (see below for more details),
- Create a repository of templates for developing ‘common look and feel’ graphics and tables for conveying risk in fisheries advice,
- Engage with clients to test various approaches to portraying and communicating risk in science advice,
- Compile case studies showing how risk-based advice could be used and should be developed. The case studies should include detailed quantitative approaches as well as scoring-based and qualitative approaches,
- Produce guidance on risk ranking, e.g., parameter uncertainty, model uncertainty and institutional uncertainty and how all these sources of uncertainty could alter the risk calculation,
- Investigate approaches to characterizing risk as a tool that can help operationalize the ecosystem approach.

Guidance would be beneficial on the following concepts:

- Understanding and exploring reducible vs. irreducible uncertainties and their relative importance in determining risk in fisheries advice,
- Black swans and tails of distributions, why and how should they be captured in the advice?
- Expressing risk as negatives or positives and the implications of that approach in advice provision,
- What is risk equivalence and how it can be used, and the uses of general risk buffers vs. calculated risk, illustrated by case studies or examples,
- The importance of specifying risk tolerance up front in developing advice and more specific guidance on making these specifications in fisheries assessments.

PART II - STOCK SUMMARIES

CONTEXT

Claims of sustainable fisheries can be defended by meeting an acceptable standard of practice for both fisheries assessment and management. Defending Science Sector advice in support of sustainable fisheries depends on several principles, including:

1. Peer-review of stock assessments and recommended management measures;
2. Reproducibility of scientific analyses, stock assessments and management advice; and
3. Consistent communication of results that clearly links the science advice to legal compliance and the preservation of policy intent.

Currently, the Department's alignment with the PA Policy (DFO 2009) is reported via the Sustainability Survey for Fisheries (DFO 2018a) on an aggregated basis over all stocks included in the survey. The survey also forms the basis of governmental audits (e.g., CESD 2016) and in large part reviews by the general public (e.g., Oceana Canada 2017, 2018). There is a particular focus on the presence/absence of reference points and assignment of stock status, despite the insufficiency of a presence/absence scoring approach to demonstrate fisheries sustainability which depends on institutional processes and cultural, social and economic considerations, not just fixed or biological attributes. One of the goals of the Science Sector implementation plan (Fish Population Science Branch 2021) intended to meet obligations of the new Fish Stocks provisions is to develop consistent Science Sector-driven reporting. Such reporting should describe what science-dependent elements are done well, what elements remain to be completed, and what plans are in place to close gaps in PA Policy implementation. Standardization can help communicate that an acceptable practice is being followed, regardless of the state of data or model poverty (Kronlund and Marentette 2019).

Guidelines are likely to contain recommendations on how science advice and reporting should be standardized, and what supporting rationale is needed when departures from recommended practices are necessary. This workshop has a role in helping to:

1. demonstrate the range of stock and fishery contexts that must be accommodated;
2. identify issues that impede the achievement of standardized reporting of status and future stock prognosis;
3. propose solutions to resolve impediments to standardized reporting; and
4. suggest effective means of communicating how science advice contributes to meeting legal imperatives and policy intent.

This "*Stock Summary*" workshop is aimed at producing recommendations for application to Science Sector guidelines.

World-wide, stock summaries are generally designed for traditional "best" assessment approaches where results from a preferred, or "base case" model, are reported, reference points are identified and some quantification of uncertainty is usually available, i.e., so-called "data-rich" contexts that rely on "*estimate the biomass and apply a harvest rate*" schemes. They are less developed for less traditional situations where ensemble modelling approaches or MSE paradigms are used. Such approaches typically produce multiple models representing different hypotheses for uncertain stock and fishery dynamics and therefore multiple sets of reference points. Consequently, a range of plausible status determinations may result. This necessary structural uncertainty can pose difficulties for summary reporting of fisheries assessment outcomes including status.

States of data or model poverty also create difficulties for stock summaries. In these contexts reference points may not be reliably estimated and therefore stock status cannot be reliably assigned, i.e., some of the PA Policy elements cannot be credibly met in the same manner as for “data rich” stocks. Part of the challenge in developing standardized reporting will be to recommend how best to represent all contexts, including those situations where species’ life history or data poverty precludes biomass estimation or determining a “precautionary” rate of fishing mortality. It is important, therefore, that a range of Canadian and international examples is considered before recommending what is best included in stock summaries and identify how each situation meets policy intent.

There is a clear interaction between what is reported in stock summaries and the degree to which uncertainty and risk can be characterized (see Part I of this workshop). Agreed-upon means of categorizing risk are needed for situations where risk can be quantified, and for situations where only qualitative evaluation is possible. Portrayal of uncertainty depends in part on the method of inference, as well the actual text, figures and tables used to represent uncertainty.

For example, without review and testing of stock summaries over a range of contexts it is difficult to determine an appropriate level of detail in reporting uncertainty – when does the ‘curse of knowledge’ lead to providing too much detail in a summary? What is the essential information needed to evaluate legal and policy alignment, status, and future stock prognosis? What information should be restricted to a more comprehensive CSAS Research Document to avoid too much detail in a stock summary, or conversely an unhelpful dilution of scientific arguments that support the components of a summary? Does reporting for certain stocks, or species groups, require specific formats (e.g., Pacific Salmon as guided by the Wild Salmon Policy (DFO 2018b), marine mammals, or some invertebrate species where “*estimate biomass and apply a harvest rate*” approaches may not be possible)? What cognitive processes should be considered when communicating risk and uncertainty to a broad audience potentially unfamiliar with interpretation of quantitative, probabilistic outcomes?

If consistent national reporting formats and guidelines defining a “standard of practice” can be proposed via Regional input through TESA, then consideration can be given to approaching CSAS to integrate the preferred practice within peer-review processes and publications. In addition to encouraging consistency of approach, a standard may reduce both the time (formatting) and costs (translation) required to produce some CSAS documents (e.g., Science Advisory Reports). It is anticipated that one format will not fit all contexts perfectly, but recommendations for a finite, documented set of reporting options will be a desired outcome of this workshop.

PRESENTATION ABSTRACTS

Cross-Jurisdictional Analysis

(Rob Kronlund)

Fisheries jurisdictions worldwide use various reporting formats to summarize stock status and future outlook (e.g., FRDC 2018, ICES 2018, Fisheries New Zealand 2018). There are usually two levels of reporting:

1. Individual stock summaries that succinctly report critical attributes of individual stocks at various levels of detail; and
2. Summaries aggregated over stocks that report the degree of alignment with a “harvest policy” (e.g., number of stocks below biological limits, number above target levels, etc.).

Fisheries jurisdictions vary in their choice of information content and data visualization for stock status. For example compare the following summaries:

a) New Zealand “brief” stock summaries;

b) New Zealand Status of Stocks Summary for Baracoutta;

c) ICES stock summary for Mackerel (selected portions);

d) NAFO stock summary for American Plaice;

e) Status of Australian Fish Stocks Reports (http://www.fish.gov.au/).

Cross-jurisdictional differences and data visualization approaches are compared more extensively in Marentette and Kronlund (2020).

Introduction to Stock Summaries

(Rob Kronlund, Julie Marentette)

The documentation of science advice in the Department can take many forms: CSAS publications, technical reports, the primary literature and inputs into public reporting venues such as the *Sustainability Survey for Fisheries*. Demand for science advice in various formats is increasing, and some of these publication vehicles suffer from delays in production, length, redundancy, etc. CSAS is currently undergoing renewal and new requirements to document science advice in relation to management measures meeting PA Policy and legislative requirements are forthcoming, as part of decision-making processes and guidance being developed under the modernized *Fisheries Act*. Recognizing that the required information for the documentation of science advice may be difficult to find, interpolate, archive and report from existing advisory templates or styles of documentation, stock summaries are being explored as an alternative. Standardized Canadian fish stock summaries may confer the following benefits:

a) a product that reports necessary (albeit insufficient) conditions to support claims of sustainable fisheries,

b) documented and consistent support for science advice informing management decisions,

c) a common “look and feel” for reporting across the country,

d) easier evaluation of alignment with regulatory requirements and policy intent (e.g., Record of Evidence supporting prescribing stocks under regulations),

e) enabling tracking, gap identification, and planning to close gaps, and

f) enhanced ability for proactive reporting out.

However, it remains to be seen whether stock summaries can be succinct yet sufficient to convey the essential information, flexible enough to accommodate many stock types, focused enough to speed publication and avoid burying the lede, clear enough to information recipients, and versatile enough to serve multiple purposes. The stock summary exercise for this workshop was derived from an example used in New Zealand, although many similar types of documents are produced around the world. One of the purposes of this exercise is obtain suggestions for scoping – are stock summary formats really the most important challenge to address here, or is identifying the critical meta-data (or derived data) that supports summaries more important? Can we identify essential outputs, help to shorten advisory documents, reduce costs of publication, and provide reproducible summaries with a common "look and feel" using more standardized language formats? While the need to repackage science advice in many forms will not disappear, metadata could streamline work and reduce duplication of effort.

Breakout sessions in this workshop focused on a) identifying principles to which stock summaries should adhere, b) finding summary elements in other jurisdictions that could improve Canadian stock summaries, and c) reviewing stock summaries section-by-section to identify elements that could improve templates.

Stock Summary Information for Ecosystem Considerations

(Pierre Pepin)

A national Working Group (WG), consisting of scientists and fisheries managers, has been formed to develop and approach with the aim of applying an Ecosystem Approach to Fisheries Management (EAFM) in Canada by ensuring that the majority stock assessments consider environmental variables (EVs) in the formulation of advice and in decision-making. The WG's strategy is aimed at working in a pragmatic and incremental manner to expand the inclusion of EVs in assessments through strengthened dialogue and engagement between Science and Fisheries Management (FM) sectors, in a manner that ensures the flexibility necessary to deal with regional issues, concerns and priorities.

A review of the use of EVs in management decisions revealed that their implications to harvest control rules (HCRs) was highly important in decision-making (Pepin et al. 2020). The review found that ecosystem and environmental considerations were most likely to be considered if included in a Precautionary Approach (PA) framework or as part of an Integrated Fisheries Management Plan (IFMP). The implications of changing EVs and the application of an EAFM in decision-making was highly dependent on demonstration, through weight-of-evidence, of a strong effect on population productivity which has important implications for long-term sustainability. This was effectively achieved using quantitative or semi-quantitative approaches to inclusion of EVs because qualitative information was much less likely to be considered in management actions.

Application of the principles of an EAFM in decision-making requires the use of plain language and simplified explanations of pathway of effect that demonstrates clear understanding of the mechanisms affecting time-varying stock productivity. Consistent use of ecosystem and environmental considerations will likely require development of standardized language and terminology to avoid discrepancies in the interpretation of recommendations emerging from assessments. The consequence of changes in EVs on recommended management action should be explicit and clear. The work of the WG indicates that Regional environmental or ecosystem overviews are an essential foundation for Stock Summary Sheets (SSSs) because stocks do not exist in isolation. Environmental knowledge should be integrated throughout the

SSSs, where appropriate, rather than as a separate section to ensure proper understanding of the pathways of effect of environmental change. The potential influence of EVs on stock status or trends must be demonstrable, robust and defendable which requires continuous evaluation of changes or shifts in the dominant drivers within ecosystems. Documenting how EVs are being considered in decision-making will require development of a standardized approach among stocks to meet requirements of revised *Fisheries Act*.

Science Outputs, Stock Summaries and the Record of Evidence

(Julie Marentette)

Visual elements can be incorporated into stock summaries – examples of these can be found in similar documents around the world. Common elements include a way to rapidly convey stock and fishery status with colours and symbols (often via a “traffic light” approach), and a graphical way to display stock status on multiple axes (such as Kobe plots). Visual elements could be placed either in “header” sections or throughout the stock summary document, but regardless of the type of visual element incorporated, colour alone should not be used to convey information.

Information in stock summaries can also be considered from the perspective of what other departmental products they might inform. Sections on stock name and structure, reference points and their bases, current stock status, management measures and other information such as bycatch could directly inform sections of the *Sustainability Survey for Fisheries* (DFO 2018a). These same components, and additional ones relating to the evaluation of management measures, could inform Record of Evidence requirements for decision-making processes. Information on assessment types, methods, data inputs, objectives, and key sources of various types of uncertainties could provide snapshots of how science advice was generated for stocks. This would provide context for peer review, decision-makers and a means by which to identify gaps for future research investments.

Canadian Science Advisory Secretariat Renewal

(Estelle Couture)

An evaluation of the Canadian Science Advisory Secretariat (CSAS) process was completed in 2019[1]. The evaluation was focused on how CSAS processes apply the Science Advice for Government Effectiveness (SAGE) principles[2]. Five recommendations emerged:

- Improve communications with clients during all phases,
- Develop a multi-year science advisory schedule,
- Operationalize the SAGE principle of inclusiveness,
- Develop a conflict of interest policy, and
- Review timeline targets to increase compliance rates for CSAS documents.

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[1] Evaluation of the Canadian Science Advisory Secretariat (CSAS) (2019). http://waves-vagues.dfo-mpo.gc.ca/Library/40909062.pdf

[2] Council of Science and Technology Advisors (CSTA) (1999). Science Advice for Government Effectiveness (SAGE). http://publications.gc.ca/collections/Collection/C2-445-1999E.pdf

Client consultations conducted in all Regions of DFO demonstrated that the utility of products from CSAS processes depended on the audience. Research Documents are valued by scientists as they represent a reference for building upon previous science work and acknowledgement of authorship. However, many non-DFO clients are more interested in the Science Advisory Reports, while Proceedings are valued by some audiences as documentation of the history of how science advice is developed but could be more concise. The need for templates to suit different types of advice requests was cited (e.g., stock summaries, aquaculture siting, updated Recovery Potential Assessments and pre-COSEWIC documents). Clients appealed to have more emphasis placed on plain language in Science Advisory Reports. Finally, the costs, quality and timeliness of translations were cited as a concern.

Stock summaries may represent an opportunity to address several of the concerns cited during client consultations:

- criticism that the advice is not made available in a timely manner,
- plain language issues,
- national consistency in provision of science advice,
- efficiency in that one product could potentially serve multiple purposes,
- potential to reduce publication and translation costs should standardized stock summaries be adopted in whole or in part for Science Advisory Reports that provide harvest advice.

However, the adoption of a standardized stock summary raises several questions related to effective communication of science advice to a target audience. For example, who are the users of SARs in addition to fishery managers? Are there instances where it would be appropriate for the stock summary to replace the current SAR format entirely? When is it inappropriate to use stock summaries to provide advice? And finally, any variation in practices will require change management to maintain credibility of the advisory process.

REGIONAL STOCK SUMMARIES

Participants prepared stock summaries based on the New Zealand template. An example template and instructions for completion were provided prior to the workshop to guide the exercise (Appendix 4). Although specific stocks were not pre-assigned, participants within each DFO region were asked to coordinate a variety of examples to include:

- a range of species groups (e.g., groundfishes, invertebrates, pelagics, marine mammals, anadromous species),
- a range of data and model poverty (rich to poor), and
- a range of perceived stock status (rebuilding candidates to stocks near historical highs).

Two outputs were requested from each participant for each stock:

a) A stock summary template completed to the extent possible by each participant,

b) Notes to describe how well source documents captured the information requested in the template. Source documents included CSAS Research Documents, Science Advisory Reports, Science Responses or other documents (e.g., primary literature).

A third output was requested from each Region to summarize the exercise in the form of a "situation report". The situation report identified the key benefits and challenges encountered when completing the stock summary templates. This section of the Proceedings reports on the regional findings. Stock summaries completed by each region (Table 9) are archived by TESA for reference. The archived summaries provide a potential resource for future development of a DFO stock summary.

Table 9. List of stock summaries by region prepared by workshop participants ordered alphabetically by region and stock. Alternating regions are shaded in grey to improve table readability.

Region	Stock
Central & Arctic	Baffin Bay Walrus
Central & Arctic	Cambridge Bay Arctic Char
Central & Arctic	Cumberland Sound Arctic Char
Central & Arctic	Cumberland Sound Beluga
Central & Arctic	Dolly Varden
Central & Arctic	Eastern Canada-West Greenland Bowhead Whale (ECWG)
Central & Arctic	High Arctic – Baffin Bay Beluga Whale
Gulf	Atlantic Herring (*Clupea harengus*) fall spawning stock in 4TVn
Gulf	Southern Gulf of St. Lawrence Rock Crab
Maritimes	American lobster in LFA 27
Maritimes	Atlantic Cod (Eastern Georges Bank)
Maritimes	Atlantic herring (*Clupea harengus*) in Southwest Nova Scotia and Bay of Fundy (SWNS)
Maritimes	Pollock 4X5 (Western Component)
Maritimes	Scallops in Scallop Fishing Area 29 West of Longitude 65 30
National Capital Region	Atlantic Mackerel, Northwest Atlantic (NAFO subareas 3 and 4)
Newfoundland & Labrador	3Ps Lumpfish
Newfoundland & Labrador	Atlantic Cod in NAFO Divisions 2J3KL (Northern Cod)

Region	Stock
Newfoundland & Labrador	Northwest Atlantic harp seals (*Pagophilus groenlandicus*)
Newfoundland & Labrador	Nunavik beluga (*Delphinapterus leaucas*)
Newfoundland & Labrador	Snow Crab (Assessment Division 3LNO)
Newfoundland & Labrador	Witch Flounder (*Glyptocephalus cynoglossus*) in NAFO Divs. 2J3KL
Pacific	Barkley Sockeye
Pacific	Fraser Sockeye – Early Summer Stock Management Unit (*Oncorhynchus nerka*)
Pacific	Fraser Spring 5_2 Chinook
Pacific	Inner South Coast Chum Salmon - Non-Fraser
Pacific	Pacific Cod (*Gadus macrocephalus*) in British Columbian waters (Areas 5ABCD and 3CD)
Pacific	Pacific Hake (*Merluccius productus*) in Canadian and U.S. waters
Pacific	Rex Sole West Coast Vancouver Island
Quebec	Northern Gulf of St. Lawrence Atlantic Cod (3Pn, 4RS)
Quebec	Northwest Atlantic harp seals (*Pagophilus groenlandicus*)
Quebec	Nunavik beluga (*Delphinapterus leaucas*)
Quebec	Snow Crab (*Chionoecetes opilio*), Fishing Area 17
Quebec	Whelk in Quebec's inshore waters

Regional participants provided the following comments on the stock summary exercise, summarized by topic, and specific comments in relation to the stock summary sections are given in Table 10.

<u>General Comments</u>

Consistency: Use the same format for each stock as much as possible to allow comparable information to be compared when viewing multiple stocks. Standard graphs as used by ICES are useful and convey a lot of information.

Use of Colour and Symbolism: Green and red as used in ICES summaries are not colorblind-proof and include a lot of social conditioning that is not universally understood. Use of different symbols may increase the amount of mental deciphering required to understand the meaning of the summarized information.

Role of Stock Summaries: Stock summaries could be used to augment or supplement SARs, but should not replace them. Furthermore, if this type of approach is not a replacement for a SAR, then a concise version with fewer elements to complete and based on standard plots from common data types would reduce workload.

Technical Support for Stock Summaries: Stock assessment results could be captured and stored in a database with quality assurance, quality control (QAQC) rules rather than a text document. The overriding criterion for application should be easy output of the derived data used for the stock summary. There should be national responsibility for data entry, governance of QAQC, and database support, and two regions noted that lessons can be learned from international database structures such as the RAM Legacy Database and Transparent Data Format (ICES).

Indicator-Based Approaches: Maritimes and Quebec Regions noted that there are numerous “indicator-based” PA Frameworks established in these regions. Thus, scientific guidelines should include consideration of how indicator-based approaches relate to the PA Policy and support the requirements of the Fish Stocks provisions. Such stocks will create obvious gaps in a stock summary that reports PA Policy elements in a systematic fashion. Guidelines are required for defining proxies for reference points defined for indicator-based assessments.

Non-Traditional Stock Assessment Paradigms: The challenges of summarizing advice obtained from assessment approaches that use multiple operating models and management procedures (simulation analyses or management strategy evaluation processes) were noted. These involve a requirement to portray multiple plausible stock trajectories, future trajectories, and trade-off plots among management outcomes related to objectives. In some instances alternative models might be combined using a weighting scheme to produce an aggregate indication of status. However, procedural approaches like MSE focus on the choice of a preferred management procedure designed to achieve a specified trade-off of management outcomes rather than focusing on current stock status. More consideration is needed in stock summaries to accommodate such approaches.

Multi-year Stock Status Updates: how would these types of updates be reflected in stock summaries?

Environmental Conditions: A section to document how environmental considerations are taken into account may be needed. Consider including an ‘ecosystem status’ section in the stock summary. Process uncertainty is very rarely communicated in advice, which may create gaps in stock summaries.

Stock-Specific Comments

Marine Mammals: Management areas for Arctic Marine Mammals are treated as stocks. “Stocks” generally contain more than one biological unit, such as age-sex-reproductive class groups or an unknown substructure that is suspected but not confirmed). Policy-based or PA Policy “provisional” reference points have not been applied to any of the Arctic Marine Mammal stocks, and empirical estimates of pristine/carrying capacity are used for reference points. Stock status in relation to common stock and fishery objectives is difficult to measure. Marine mammals such as Harp Seal have analogs of PA Policy reference points, however the templates may not provide sufficient space for marine mammals. In some cases, transboundary issues complicate management regimes such as for Eastern Canada-West Greenland Bowhead Whale (ECWG). For ECWG Bowheads, Canada is collaborating with Nunavut and Nunavik Inuit to develop an Integrated Fisheries Management Plan, but Canada and Greenland require an international forum to discuss their shared management and sustainable harvests.

Scallops in Scallop Fishing Area 29 West of Longitude 65 30: This stock is an aggregate of multiple, separately assessed sub-units (5). This designation was made because of the sedentary nature of scallop and significant variability in productivity across the stock area. In sub-units where a LRP has been established, it is set at 0.3 D_{MSY} where D_{MSY} is the density in tonnes per km^2 associated with MSY. Note that all the reference points for subareas B-D are for the “high” quality habitat areas of scallop within the subareas to reflect variable productivity within each subarea. It is unclear whether this level of detail needs to be captured in stock summary. Thus, this scallop stock represents a good example of the challenge of identifying a single LRP for the stock when reference points are actually defined at a sub-unit level. It is not clear what aggregate measure of status should be applied or whether the stock should be disaggregated into the constituent sub-units.

Groundfish: While Northern Cod (2J3KL) and Witch Flounder would be amenable to the stock summary format, data-limited stock such as Lumpfish are more difficult to report using the supplied template. Similarly, stocks that use qualitative indicators or “traffic light” approaches cannot easily be accommodated.

Fraser Spring 5_2 Chinook Salmon: Although data for this stock management unit (SMU) are limited, the high profile of the stock has resulted in several science advisory documents in recent years, which is uncommon for most salmon stocks. In considering reference points, objectives, and stock status, there are Wild Salmon Policy benchmarks identified at the Conservation Unit (CU) level. However, there is no established approach to roll these up to the Salmon Management Unit (SMU) level as would be required if a one stock, one LRP requirement is applied to meet obligations of the revised *Fisheries Act*. Management goals are not stated as measurable objectives in the salmon IFMP or the Pacific Salmon Treaty. The overarching management objective identified in 2019 was to avoid exceeding a limit fishing mortality rate (not biologically based) rather than stock status and fishery objectives defined over a long term. There is no single “assessment method” applied to Pacific Salmon. Different methods get used for different purposes (e.g., escapement estimation, exploitation rate estimation, forecasting, reference point estimation) and for different scales of management (Pacific Salmon Treaty stocks vs. domestic stocks). For Fraser Spring 5_2 Chinook Salmon, the template was completed by identifying four major assessment methods for the SMUs that are used annually to inform management decisions. These were summarized in the “Data” and “Assessment” sections of the example template for each of these methods. Hatchery enhancement was addressed by extracting some information from a recent Wild Salmon Policy (WSP) Integrated Status Assessment (Brown et al. 2016), but it seems that documented summaries of enhancement by SMU are not readily available. Enhancement by site is available from DFO the Salmon Enhancement Program (SEP) website (https://www.pac.dfo-mpo.gc.ca/sep-pmvs/index-eng.html) as raw data that would need to be aggregated into summaries for each SMU.

Atlantic invertebrates: With invertebrate stocks such as these, there may be several stocks or several management areas for which advice is provided by each stock/area. It may be challenging to complete 9 (Snow Crab) or 12 (Whelk) summaries or one summary each with 9-12 sub-sections. In the case of Snow Crab, advice is provided on three scenarios with different probabilities of maintaining the biomass, and it is unclear how such advice scenarios may be represented in the stock summary sheet.

Table 10: Comments provided by Regions on specific aspects of the Stock Summary exercise.

Section	Regional Comments on Stock Summary Exercise
A – Stock Description	• Providing information around stock structure assumptions may be challenging, but this may be an important link to the choice of LRP. • Stock structure – the evidence basis is often unclear for stock structure and may be defined on the basis of legacy practices or management units. • Adopt a formal taxonomic treatment (e.g., species level, group, use the World Registry of Marine Species, http://www.marinespecies.org/). • Formalize stock area description so a map reference can be provided. • A template will need to accommodate multiple management units for different levels of stock organization, regardless of whether units are based on management or biological considerations. • For section **A2- Stock structure assumptions/basis** there needs to be provisions for clearly presenting/distinguishing the stock structure hierarchy (e.g., stock vs biological components vs management units).

Section	Regional Comments on Stock Summary Exercise
	This is likely to evolve over time as new data (e.g., genetics) become available. • In A3- Assessment approach more options are given for data-rich assessment approaches (i.e., ensemble, simulation, MSE, etc.) than data-limited (indicators). Other (data limited) options may involve 'model-poor' and life-history based approaches. Assessment approach classification may require a priori 'triage' of stocks into tiers (e.g., tier 1, tier 2 and tier 3 stocks), with each tier broadly defined based on data and knowledge availability. No such classification currently in place in Canada.
B – Reference Points	• Objectives are not normally articulated in advice for many fisheries. Possibly default objectives could be provided for guidelines and Terms of Reference for assessments. • An option for "forecasting" is needed as well as for feedback simulations. • There is limited application of reference points in the form of Wild Salmon Policy (DFO 2005) benchmarks. The PA Policy default reference points based on (0.4, 0.8) B_{MSY} are often applied. • B9 – Conservation objectives is not clearly defined**;** is this intended to state whether harvest control rules are in place? • B11- Evaluation: Unclear and potentially superfluous. The information sought in this section will only apply to a limited number of stocks and may be best as a standalone section somewhere else in the summary.
C - Data	• This section is subjective and may require more guidance around "quality" versus concepts like 'best available science' in peer review. • What qualifiers would apply to CPUE data that can be estimated with little error but may not be a good quality index of abundance? • Additional clarification is needed on the level of data descriptions (e.g., area, time, survey coverage, etc.) • New Zealand has process for assigning data support, etc. that would need to be defined for application in Canada including a ranking system for data quality. • There is confusion as to what is 'used' vs 'not used' data. Clarification is required on what should be included or not in the 'data not used' (C2) section (e.g., do we really want to include all available indices not used to provide advice on stock status?). Data quality ranking and rationale for inclusion/exclusion may require a separate process (e.g., a priori review of the available data and information for assessment). There is no such process within DFO at present. This section only deals with empirical and scientific data sources. Other information bases for the assessment (e.g., traditional or harvester knowledge) could be included here.
D – Assessment Methodology	• Include information to report assessment methods that were proposed and rejected or that have been discontinued. This may clarify when "indicator-based" assessment methods are used. • A category may be needed to describe the basis for assessment frequency related to model poverty. • More consideration is needed for the categories to describe types of assessments (e.g., "age-structured stock assessment", "delay difference model", "closed-loop simulation based on operating models conditioned with model type"). • Pacific Region noted differences in approaches for salmonids, groundfish and invertebrates. Salmonids have different objectives applied at multiple spatial scales and may have multiple assessment methods so categorizing the assessment approach requires more development.

Section	Regional Comments on Stock Summary Exercise
	• Section D: Assessment Methodology: Assessment type (D1) and assessment approach (A3) are redundant. Basis for assessment frequency (D5) is often capacity-based or based on species biology. There is also a need to include stock updates (whether they are conducted, when or under what circumstances, and at what frequency).
E – Management Measures	• Indicate the management jurisdiction. • Link the management measures to licensing information if it exists. • This section is important because measures and their rationales are rarely all found together in one source. • All stocks, regardless of life history, may apply a mixture of input and output controls. • It was suggested that a distinction be made between the science advice and subsequent management decision so that implementation error could be tracked. • In some cases HCRs are not clearly identified, nor applied (e.g., one Atlantic Herring stock, one Snow Crab stock). • Section E : Management Measures: Suggest merging this section with the reference points (section B)
F – Historic Stock Trajectory	• Panels could be arrayed in a single column so that each figure is larger, and consider adding a section for trajectory of landings or catches (retained and discarded) over time. • It may be difficult to know how many figures or tables to provide. • The need to accommodate empirically based trajectories in the template was noted, although little modification would be required. • Characterization of stock trajectory should accommodate evidence using a strong empirical basis • Stock status and trajectory information should appear first in the summary • This section could include landings and/or fishing effort trajectory
G – Current Stock Status	• Needs guidance for how to complete this when only point estimates are provided. • Information on stock status should occur near the beginning of the template. • Assessments are sometimes based on multiple indicators that may be qualitatively combined. In such cases guidance is needed for how to report the indicators and how they are combined to form a status determination • Section G: Stock Status: could combine and harmonize stock status and trajectory (sections F and G) including links to the PA Policy approach and stock status categories (healthy, cautious and critical). • Should this be left blank if no reference points?
H – Stock and Fishery Trends	• Relatively easier to complete in narrative form as this information is common in SARs.
I – Projections and Prognosis	• Consider including a conclusion describing stock perspectives section at the end of the summary. • Section I: Projections and Prognosis: For data-limited assessments/stocks, it might be useful to define stock prognosis qualitatively. This might require a set of rules or options. Where quantitative assessment and projections are feasible, a table summarizing the scenarios considered in projections might be useful.
J – Other Information	• Further guidance on quantifying what “main bycatch” means would be helpful

Section	Regional Comments on Stock Summary Exercise
	• An important element missing from the exercise template is a table on the 'history of advice, catch and management' as found in ICES advice sheets • Consider including background biological information and ecosystem considerations in the summary • Is it acceptable that relevant biological information and ecosystem considerations such as fisheries bycatch and fisheries interactions be consigned under the 'other information' section?

Breakout Exercises 5-7

Exercise 5: Principles for DFO Stock Summaries

Objective: Identify principles for a DFO stock summary

Various international jurisdictions have developed standardized reporting for providing summarized information on stock status and prognosis. Reporting varies in the degree of detail provided in terms of historical outcomes and explanatory narrative. A cross-jurisdictional review by Marentette and Kronlund (2020) recommended that science guidelines for Canadian stocks should at minimum:

1. Outline formats for standard reporting of stock and fishery status to facilitate rapid communication of science advice (e.g., Science Advisory Reports), including any accommodations for data-poor stocks,
2. Reflect status relative to limit, target and other reference points in both biomass and fishing mortality axes, as required under Canada's PA Policy or as outlined in objectives related to the Fish Stocks provisions and subsequent regulations, and
3. Integrate the reporting of stock status with reporting associated uncertainty.

In considering an approach for Canadian stocks, it is an open question whether stock summaries can be:

1. ***Succinct***, yet sufficient by including essential information related to:
    - required PA Policy elements such as reference points, management measures to avoid limits and achieve targets, uncertainty and performance evaluation,
    - status relative to reference points,
    - stock trajectory (past and future),
    - communicating risk (probability) of avoiding or achieving outcomes of interest,
    - taking "biology and environmental conditions" into account as per the legal language in the Fish Stocks provisions.
2. ***Flexible***
    - to accommodate a variety of life histories,
    - to admit a continuum of data and model poverty from poor to rich.
3. ***Focused***
    - to avoid burying the lede by emphasizing what is (reasonably) well-known,

- to avoid including details associated with the technical underpinnings of the stock summary information that is better captured in other documents (e.g., CSAS Research Documents),
- via standardized formats and language to provide a consistent “look and feel” and decrease publication delays.

4. ***Clear***
    - so fisheries scientists and fishery managers agree on interpretation,
    - to decision-makers and the public.
5. ***Versatile***
    - to provide information or citations to support the Record of Evidence supporting the Fish Stocks provisions that documents advice to decision-makers,
    - to provide inputs required by the DFO Sustainability Survey for Fisheries to avoid repeated submission of the same information independently for a variety of reporting tasks,
    - to potentially provide information for CSAS Science Advisory Reports,
    - outputs for reporting and performance tracking in ways that may be tailored to a variety of audiences.

Breakout Exercise 5 (Table 11) was designed to stimulate discussion among participants on what is important for DFO stock summaries.

Table 11. Description of breakout exercise #5.

Breakout Exercise #5 (45 minutes + 45 minutes presentation time) • Identify **principles** for a DFO stock summary. • Possible principles (you are not restricted to these examples): 1. Succinct – avoids drowning in details and burying the lede, 2. Flexible – accommodates a variety of life history types, data poor to rich, 3. Focused – the elements are the minimum set to inform a decision, 4. Clear – documented, consistently applied, reproducible, and 5. Versatile – underlying metadata could be repackaged. • Prioritize principles 1-5, **plus your principles,** and describe how to operationalize the top 2 principles. • Appoint a group member to present your list (**5 minutes each group**)

The breakout groups provided their priority principles and supporting explanations that generally included the suggested principles, but also included some additional considerations (Table 12). Specific comments were provided on operationalizing a stock summary.

For example, it was suggested that principles cluster into two categories. The first category “content” included the principles of being *succinct*, *focused* and *clear*. The category “document creation” included the principles of *flexibility* and *versatility* to make production of stock summaries easy and efficient. Groups noted that stock summaries must be easy to produce and useful for both the authors and the audience. Elimination of redundancy emerged as a common consideration for several groups. It was noted that many types of information, like biology and fishery information, will be largely consistent among years and would not need frequent updating.

Automated document production using RMarkdown can be useful in such applications (e.g., Anderson et al. 2019) if standardized data files are adopted. Redundancy in producing reports is not sustainable by science staff, so a stock summary should not duplicate existing CSAS documents or the Sustainability survey for fisheries. It was noted that CSAS documents are not always produced for some stocks (e.g., for Pacific Salmon) on an annual basis; therefore, status updates will differ by stock and in the case of Fraser Sockeye Salmon, will have multiple documentation instances in-season and possibly in the same week.

Three other themes emerged among the groups related to identifying the intended audience for stock summaries, steps to operationalize stock summaries, and technical issues:

<u>Intended Audience</u> - The importance of knowing the audience was cited by several groups to define the *purpose* of stock summaries, which is essential to proper design of both the format and any software application(s). It was noted that fisheries managers require concise, advice that is consistently portrayed for decision making. Therefore, an important design feature for stock summaries should be consideration of *utility for purpose* which was assumed by several groups, i.e. for management decision purposes. Other groups posed whether a stock summary should be intended for fishery managers, Indigenous communities, industry or the public? One group recommended that end users and scientists should be brought into the discussion on a species-specific basis, or by groups of species (e.g., marine mammals, salmon, etc.), to identify any necessary adaptation of a standard.

In NAFO stock summary sheets, a table is located near the top of the sheet describing the management objectives for the stock. The NAFO sheet is the key document that mobilizes what advice is available. Traffic lights (red/green/yellow) indicating status need to be updated out each time a sheet is produced and should be automatically populated based on responses. NAFO sheets have also *evolved over time;* sections get added or deleted, and NAFO is currently considering a departure from the objectives that are currently in use. It was noted, however, that the concept of traffic lights is also not generally intuitive (e.g., parts of the Arctic do not have traffic lights). One group favored a stock summary template like the ICES example (ICES 2017), emphasizing the need for a graphical presentation with stock status emphasized at the beginning of the summary. Other suggestions included reviewing State of the Ocean reports[3] for ideas on clarity and focus.

<u>Operationalizing Stock Summaries</u> - One group suggested that there are two phases to the development of stock summaries:

1. *Development phase* – necessarily iterative and incremental development of the stock summary template to test the utility of stock summary formats, and
2. *Delivery phase* – for operational implementation of stock summaries.

One of the group suggestions was that a smaller subset of stock summaries be generated to test the formats and document production process. For example, Batch 1 stocks proposed for prescribing under the Fish Stocks provisions, or case studies being developed by the Ecosystem Approach to Fisheries Management Working Group could serve as pilot examples.

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[3] https://www.dfo-mpo.gc.ca/oceans/soto-rceo/index-eng.html

Subsequently, the results of such an exercise could be reviewed and stock summaries revised before a more extensive set of summaries are prepared.

Technical Issues - Various groups suggested stock summaries should:

- be data-driven,
- be supported by software (e.g., scripting to produce the summaries) with derived data stored in a relational database,
- allow for any necessary regional modification,
- start with a national effort to provide standardized design and code for figures and tables but regions would be responsible for supplying the standardized inputs,
- use standardized "tidy" tables (https://www.tidyverse.org/) supported by a national derived-data database similar to the RAM Legacy database (http://ramlegacy.org/),
- include null data in a stock summary by indicating missing metrics and providing the reason for the absence (e.g., insufficient data, no agreement at the peer review stage),
- accommodate a model-driven subset of metrics for a stock summary, where applicable (e.g., parameters, model type, discarded models),
- time-stamp the information based on when specific elements of the summary were determined or estimated, and
- be adaptable to new data or assessment methodologies.

Table 12. List of additional principles and explanation for stock summaries.

Principle	Explanation
Succinct "Simplicity"	Emphasized as the principle driver, with other information complexity added later. It was advised to 'start small', for example with a short, concise, 1-pager. Additional data fields can be added subsequently. Brevity is a key attribute, none in NAFO series are longer than two pages. Groups noted clear and succinct as the most important priority for a DFO stock summary. The summary should be consistently applied across all species groups and easily reproducible from one stock summary to the next.
Flexible	Different stocks may need to include different sections ("headers"), categories, or types of information. Other types of information may be need to be included for specific cases. One strategy is to include certain core sections, such as stock status, trends, etc. but have latitude to include other important information (e.g., hatchery supplementation). The stock summary will need to be able to accommodate a variety of life history types and species groups with various levels of data support. However, the stock summary template should be consistent across species as much as possible; one group felt flexibility was not one of the most important principle. One group liked the idea of having the same general look and feel of the output documents, but commented that there needed to be some flexibility in the input and the process. Standardization in wording was considered important, which can be

Principle	Explanation
	achieved by using drop down menus should summary production be automated. This may warrant future discussion to strike an acceptable balance between restricted choices and flexibility.
Clear	One group concluded that *clarity* was the most important priority for a Canadian fish stock summary. Particularly for the metrics associated with the PA Policy, a clear understanding and consistency across stocks in Canada is required. One group felt that all of the subsequent principles after *clear* should be binned together equally. They all had their merits and were necessary for a stock summary. Although *succinct* was included in this group of principles, it was felt that it would only be necessary in specific situations like briefing materials and potentially CSAS documents. Similarly, focused stock summaries may be required for specific situations, but the underlying data could be more comprehensive.
Versatile “Transformable” “Updateable”	The summary should be versatile, but consistent across species. For example, larger databases could be constructed from the derived data reported in a stock summary to allow alternative reports to be easily generated. As approaches evolve, the transition of information among stock summaries needs to be considered; how is an entirely new assessment methodology with implications for reference points and other PA Policy elements to be reported? One group felt the purpose of the stock summary was a process for giving information and not retrieving data. This principle was the least important.
Efficient	Ease of editing and roll-up is key – maintaining textual statements but revising values each year is preferable to reduce effort. Many things like overall biology and fishery information are unlikely to change substantially each year, and can be carried forward with progressive iterations. R Markdown can be useful here, with formalized data files, in a system that anyone can use and access. CSAS documents are currently experiencing backlogs in production due to translation costs. The intent is not to reproduce the SAR or the Research Document, as those are separate documents and repetition is not sustainable. The intent also should not be to duplicate the Sustainability Survey which is long and needs to be wholly redone each year with new and old questions. One breakout group felt that an additional principle should be added to the list: *Efficient/Comprehensive*. They felt that a fish stock summary needed to include enough information to be utilized in a variety of different formats and situations. This may reduce the need to fill out many spreadsheets and forms and is useful for different client groups. Easily updated.
Standardized	Being succinct and graphic was also considered important. Several key types of graphs, for example, could be in all sheets – such as the index of abundance or times series of (estimated) spawning biomass series, survey indices, recruitment index, fishing mortality, relative F, etc.
Peer-reviewed	The idea of having these documents peer-reviewed was based on the assumption that they would either replace the SAR, or be used as a quick tool to get the main science advice from the CSAS meeting disseminated. That is, if the stock summary is used as a way of publishing the science advice so that it is available quickly, then

Principle	Explanation
	these documents themselves should be peer-reviewed. More discussion is needed pending clarification of the purpose of the stock summaries.
Inclusiveness	There should be components of the stock summary for TEK, ecosystem considerations, expert knowledge/opinion.

Exercise 6: Cross-Jurisdictional Comparison

Objective: Contrast an ICES stock summary with the New Zealand “homework” template. Consult the “basis for advice” document for ICES if necessary.

International examples of stock summaries vary in the emphasis on information, amount of detail, and presentation format. For this exercise (

Table 13), breakout groups compared examples of ICES stock summaries with the template adapted from New Zealand that was used for the pre-workshop homework (Appendix 4). Three different ICES stock summaries were used for the exercise, representing a range of "data poor" to "data rich" stocks:

- [Tier 1 "data rich"]

  ICES. 2017. Haddock (*Melanogrammus aeglefinus*) in Subarea 4, Division 6.a, and Subdivision 20 (North Sea, West of Scotland, Skagerrak). June advice. In Report of the ICES Advisory Committee, 2017. ICES Advice 2017, had.27.46a20. DOI: https://doi.org/10.17895/ices.pub.3118,

- [Tier 3 "survey-based index assessment"]

  ICES. 2019. Sandeel (*Ammodytes spp.*) in Division 4.a, Sandeel Area 5r (Northern North Sea, Viking and Bergen banks). In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, san.sa.5r, https://doi.org/10.17895/ices.advice.4724,

- [Tier 5: "landings only, low information"]

  ICES. 2019. Tusk (*Brosme brosme*) in subareas 4 and 7–9, and in divisions 3.a, 5.b, 6.a, and 12.b (Northeast Atlantic). In Report of the ICES Advisory Committee, 2019. ICES Advice 2019, usk.27.3a45b6a7-912b, https://doi.org/10.17895/ices.advice.4823.

Groups were asked to focus on elements related to stock status and prognosis, issues relevant for the choice of assessment approach, and the communication of uncertainty and risk (

Table 13). Pros and cons of each style of stock summary were to be evaluated, as well as how well each approach related to the principles discussed for Breakout Exercise #5.

Table 13. Description of breakout exercise #6.

<u>Breakout Session #6 (45 minutes + 45 minutes presentation time)</u> • Compare an ICES and the New Zealand (homework) stock summaries. For ICES, consult the “basis for advice” as needed. **Each group has only one ICES type to consider** (data-poor, data-moderate, or data-rich). • Focus on the following elements: 1. Stock status and exploitation status (reference points) 2. Stock trend over time and future prognosis 3. Issues relevant for assessment (key drivers of dynamics?) 4. Communication of uncertainty and risk (consistent? clear?) • Identify which stock summary best captures the elements. • What features do you really like? What features do you dislike? • Are there situations in Canada that do not fit either the ICES or New Zealand stock summary? • Do the ICES and New Zealand summaries meet the principles from Breakout Exercise #1?

Comments and questions based on the exercise were collated across the groups. Pros, cons and the best and worst aspects identified for each stock summary format are given in Table 14 and Table 15.

Table 14: Comments received on the ICES Stock Summary for Breakout Exercise #6.

ICES Stock Summary Comments	
BEST ASPECT: The entire first page (better tells the story on a single page with graphics, icons and advice front and center). PROS • Common/standardized look and feel. • The template is easy to follow and is visually appealing with informative symbols • Information is accessible to various end users and more useful for fisheries management decision making (e.g., clear stock status). • Viewed by many groups at different levels during review. Reduces potential for narrowly focused details being included in final version. • Brevity - agreed-upon rules with more background infrastructure. For that reason the template is more concise and constrained.	WORST ASPECT: lack of probabilities and risk, lack of projections. CONS • Could be clearer for some elements. • Missing references to figures in text, and showing PA ref points alongside MSY ref points without specifying which forms the basis for advice is confusing. • Brevity can also be a weakness for providing explanatory detailed information. • Some confusion of the stock structure presented in the history table. • No ecosystem considerations explicitly stated. • Having the data-limited example, we had only 1 large figure. We felt that having the 4 mandatory figures (Catch/landings, F, Biomass, Recruitment) would highlight what information we have and don’t have for each stock.

ICES Stock Summary Comments	

• Updates would be simplified with this format. Some categories would only have to be populated once.
• The early portrayal of the science advice beneficial (don't bury the lede). The take home message on the status of the stock is in the first line. Could follow with basis for advice.
• History of advice, catch and management information provided in tables.
• Multi-year stock and exploitation status provided.
• ICES better captures quantitative uncertainty because plots are standardized with colours.
• The four plots could consist of:
  ○ Catch
  ○ Stock Status
  ○ Choose from: recruitment, environmental variability, size distribution, age composition
  ○ Choose from: recruitment, environmental variability, size distribution, age composition
	• No Traditional Ecological Knowledge information
	• Lack of probabilities/risk; lack of projections
	  ○ not presented upfront in the advice with regard to the recommended catch and confidence with regard to the evidence they are displaying
	  ○ but no mention of the uncertainty (ie., high, med, low)
	• Missing references to figures in text, and showing PA reference points alongside MSY reference points without specifying which forms the basis for advice is confusing.

Table 15: Comments received on the New Zealand Stock Summary for Breakout Exercise #6

New Zealand Stock Summary Comments	
BEST ASPECT: only three pages long, and the wording around risk PROS • The template is more tabular in format and contains more information. Format places an emphasis on the examination of the data, data types and availability. • Instructive table headings clarify table contents and meaning. More sub-headings also make information easier to find (e.g., LRP). • Some felt this format was easier to follow. There were agreed-upon rules for use and application, more background infrastructure and documentation. • This format would be easier to feed into a database. • Explain likelihoods using IPCC language relative to the LRPs	WORST ASPECT: less visually appealing overall CONS • Only provide advice one year out, no multiple catch options. • Difficult to skim quickly for information. • Neither visually compelling nor a great use of space. • Too much text/narrative – graphs would be easier to follow. • No place for the history of the advice. • May not work well with non-commercial species • No ecosystem considerations explicitly stated. • No mention of the environment or any external drivers • No TEK information. • NZ format does not work well for non-commercial species (SARA, marine

New Zealand Stock Summary Comments	
• Contents of age-structured (YOY and spawning), by-catch and discards, habitat and ecosystem are very instructive. • Some felt this format was more flexible: they felt there was less restriction on content and had the advantage of being able to provide a narrative to accompany the assessment. • Others felt this format was less flexible: More concise, more constrained, more structured and more prescriptive. • Starts with the advice, i.e., take home message is the first line. • Socio-economic objectives were given consideration in the summary. • Can rank data/information quality. • Like ICES, this is viewed by many groups at different levels. Reduces potential for narrowly focused details being included in final version. • Instead of four plots (ICES), the NZ format had one plot with primary index, catches and TAC that may make it more easy to line them all up. • More useful for supporting the proposed Record of Evidence in support of the Fish Stocks provisions (e.g., clearly identified LRP). • NZ provides opportunity to include additional uncertainties (*e.g.,* Reference Points, ecological, species interactions).	mammals, etc.) as many of the fields would be blank.

Conclusions from Breakout Exercise #6

Overall, some participants favoured the NZ format, while others preferred the ICES format. If the intention is to replace the DFO SAR, some participants thought that the NZ format should be favoured (as it was more flexible), while others suggested that the NZ format needed to be better standardized and simplified (e.g., clear statements of stock structure). The ICES format would simplify updates as some categories only have to be populated once. The ICES format is also visually appealing but needed a legend for the symbols. Figures were preferred to tables, but if figures are included, it is important/convenient to have them automated so the underlying data would need to be available in a database and it was thought that there needed to be better visualizations of maps as well as the data gaps. Standardized language was supported.

Comments by the groups were often in agreement for many elements of the two styles of stock summaries, but not always. Most groups appreciated the graphical elements of the ICES-style summary for both the status indicator symbols and the standardized figures. In general participants liked the compactness of the ICES summary and agreed with the inclusion of historical data, management parameters, and harvest recommendations. The ICES summary better captured stock trends over time and prognoses.

Many groups noted that the choice of stock summary format would depend on the audience, commenting that the ICES stock summary best captured essential elements but the NZ format might be favored as a replacement for a CSAS Science Advisory Report based on the flexibility of content, easier to find content such as status and reference points, and generally greater amount of information provided. In particular, the ability to include a narrative in the NZ-style summary was noted.

One of the values of the stock summaries for portraying stock status in a consistent format. It would be important to have a consistent format for all species and stocks. Species groups should not have separate template formats for each species in a group. However, a challenge remains for stock aggregates. Some stocks, like marine mammals and salmon, have have different types of management decisions due to multiple scales of management objectives and measures (e.g., enhancement, habitat restoration).

The group participants particularly liked the rolled-up summary of the status of all New Zealand stocks (“Fisheries Assessment Plenaries;” e.g., Fisheries New Zealand 2018) and recommended that this type of document be examined further.

Ultimately, it may be that a stock summary that is a blend of the ICES and NZ styles might work well, combining the desired graphical elements and information content at a level between the two approaches. Both styles have similar coverage of important aspects related to stock status. One group suggested the ICES template could form the front-end of the Science Advisory Report while the NZ-style template could provide the back portion with the history of management decisions and relevant historical data in a manner similar to existing CSAS SAR documents and the ICES historical summary table.

Exercise 7: Stock summary "deep dive"

Objective: Critical review of "homework" stock summary template.

Table 16. Description of breakout exercise #7.

Breakout Session #7 (1 hr + 1.25 hrs presentation time) Our task is to revise (if necessary) the summary Topics A-J from the homework template to prototype a "DFO stock summary" (plus new Topics H-K). Each group has different Topics (there is some overlap among the groups). Each Topic has a set of questions to address developed from your homework. You are free to lump or split Topics, or identify a new Topic, or even determine a Topic should be omitted. Appoint a group member to present your recommendations (10 minutes per group). Things to remember when modifying the stock summary: • Remember the **Principles** developed in Exercise #5 • Be ***ruthless*** about the **Curse of Knowledge** • Don't "**bury the lede**", emphasize what is likely, very likely, almost certain • Keep **standardization** in mind – do your modifications apply across different life histories and states of data- and model-poverty? • Long stock summaries take longer to complete… more work… • What elements can be deferred to background materials? • What elements are not "Science", but are needed for a summary? What could you omit without losing key decision-making information?

Comments from participants regarding the "homework" template are presented below, grouped according to each subheading in Table 17.

Table 17: Comments received from participants regarding the "homework" stock summary template for Breakout Exercise #7.

Section	Comments
A - Stock Description	• Both common and Latin names are important, possible Registry name • Should include four fields: Region, management area, common and Latin name • A challenge for stocks where advice is provided for each subunit (aggregate stock challenge)
B - Reference Points	• Reference points and their basis should definitely be included (may need some alternative term for "proxy". Some jurisdictions like ICES have prescriptive methods for this – could lead to creating a drop-down list for selecting the basis. Drop-down menus could be used for a lot of things. • Clickable references to documents to explain what things like $B_{recover}$ are would be helpful (a need for a glossary, or links to other published documents)

Section	Comments
	• Confidence intervals and objectives may not be needed in this section. Perhaps link to the IFMP; unless this is an MSE, in which case a different format may be needed. • There is a need to situate the stock in its PA framework to explain the decision. • Keep section short and simple. The bulk of the document should focus on stock status and trend. • The template should be flexible enough to allow specification of different reference levels. Guidance may be necessary. • Clearly indicate reference period. • Table used in ICES stock summaries is a useful and effective way to present the information. • Separate biological versus socio-economics information. • Sections 9 (conservation objectives), 10 (fishery objectives) and 11 (management procedure evaluation) should be moved to management section. • Formalize the formulation of clear fishery objectives.
E – Management Measures	• Include link to management plan (IFMPs) if possible. • Include multi-fisheries management considerations: e.g. right whale vs snow crab; redfish vs shrimp. • Add management history table (similar to ICES stock summary) to get a better understanding of outcome uncertainty.
F – Historic Stock Trajectory	• Similar to the ICES summary sheets, it would be good to include the science advice along with the historic stock trajectory and move this entire section to near the beginning of the summary sheet. • Suggest having the following four relevant figures in this section: 1) Catch/landings, 2) F, 3) Biomass, and 4) Recruitment. Proxies could be graphed for each of these. • Only show what we have and have explicit wording about data inputs (limited, moderate, rich) might be the better approach. It would be good to have a common look and feel, but adaptable to the different situations. • For including projections this section, we thought it would be a good idea but some thought would need to be given to what catch level you use for giving the projection. This information would also be provided in more detail in a projections section, and would not be included for all stocks.
G - Current Stock Status	• Status in relation to limits is very important, and here is where uncertainty should be brought in. • We can report % over B_{lim}, or the ratio of B:B_{lim}. Standardized risk language will help here. • Trends and direction should also be reported. • This section should be moved up, after the stock name. Could include a Kobe-type plot. • Overfishing/overfished terminology could be used in science advice to supplement Healthy/Cautious Critical.

Section	Comments
	• Q1 – Status in relation to limits: We like the IPCC terminology[4] so that we can have probabilities in our stock status. Compared to the PA policy categories for “defining risk tolerance designations”, we think that IPCC has better ranges and categorizations for describing likelihoods. • Provides uncertainties in digestible form (easy to understand). • For how probability statements could be given, we did not like the example of “1-in-10 year chance”. Adding “year” here was a resounding no. Also statistically ambiguous and difficult to explain and as such, preferred probabilities (with confidence levels) over natural numbers. • There was discussion as to whether to include the IPCC range in the statement or the number itself. e.g. It is unlikely (0-33% probability vs 30% probability) that the stock is below the LRP. There was preference to give the exact number because the range (e.g. 66-100%) is quite large and could be misinterpreted. • For instances where probabilities could not be provided, we thought that communicating something about the confidence in the data and indices is better than nothing, so follow a modified version of Figure 1 (IPCC). • Giving probability of being BELOW the LRP is probably better to communicate risk. • A phase plot would be good to include to show stock status in relation and targets (when available). • Q2 & Q3 - Status in relation to overfishing (Q2) and target(s) (Q3): For both of these sections, we did not feel that it was up to Science to decide if “overfishing” and “overfished” should be adopted. • It would be possible to adopt these, but felt the definitions for each would need to be worked out. For example, “overfished” is highly dependent on the definition of target removal rate, which may not be consistently applied across stocks. More discussion could be warranted.
H – Stock and Fishery Trends	• This section could be captured entirely in the “Current stock status” section as opposed to having its own section. This could be done by simply added a “trend” column to the current stock status section. • For the definition of recent it might depend on the individual stocks. This would be informational rather than a decision point for the advice section.
I – Projections and Prognosis	• The type of projection should be indicated. • A time horizon rationale should be provided.
J – Other Information	• Ecosystem Considerations should not be in other information section.
Additional Section - Habitat Interactions	• This section could be folded into ecosystem interactions. Standard statements could be possible to have here. The goal is to understand causation of link from habitat change to stock productivity.
Additional Section - Ecosystems Considerations	• Ecosystem variables should be considered in different areas and integrated into different sections of the stock summaries. Possibly not a separate section. As an example, predator requirements should be part of LRP information.

[4] https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/ch1s1-6.html

Section	Comments
	• Conceptual diagram could be used as an upfront tool. Include simple figure wire diagram of ecosystem toward the beginning of the document. This would force into the stock summary the idea to include ecosystem dynamics. Rank importance of links in the diagram.

SUMMARY OF PART II

General Feedback on Stock Summary Template

Participants noted that over time there has been an unsustainable increase in the repackaging of different Science outputs (both Regional and National), including CSAS products and the *Sustainability Survey for Fisheries*. Operationally, it is important to consider whether a stock summary format would be work that is performed in addition to, versus instead of, these other existing outputs. That determination would affect what attributes of a stock summary are desirable and which may be unnecessary or redundant.

Templates seem to be most easily conceived of for simple fisheries science advice cases, meaning traditional stock assessments on one stock using a “single best model” approach. Management strategy evaluations, ensembles, or aggregate stock situations become more challenging to accommodate. Templates also do not handle information on environmental conditions or traditional knowledge well, although the work of the Ecosystems Approach to Fisheries Management Working Group will inform the former. Other aspects of harvest strategies, such as management objectives and measures, may be more challenging to include as they are not within Science mandates.

Regardless of what option is chosen, templates should be accompanied by detailed criteria and clear instructions, and graphic design should be carefully taken into account.

DISCUSSION

EXTERNAL EXPERT CLOSING REMARKS

Observations and Recommendations (Dr. Randall Peterman, Professor Emeritus and Former Canada Research Chair in Fisheries Risk Assessment and Management, Simon Fraser University)

These summary remarks were provided by Dr. Peterman on the final day of the workshop. He commented that the workshop was well designed with a mix of presentations and breakout groups. The latter worked on well-focused issues, and people were deeply engaged in the tasks set out for those breakout groups.

The main thread common to most of the workshop dealt with communication problems. One of these was a frequent lack of clear management objectives. Clarity is required so that stock assessment scientists can provide managers with the most useful advice. Dr. Peterman provided a number of recommendations:

Recommendation 1: If the management objective is unclear, stock assessment scientists could conduct sensitivity analyses across different plausible objectives. Output from those analyses could then focus on how those different objectives change the rank order of management options, thereby narrowing down subsequent discussions with managers to whether uncertainty about their objectives would make a difference in their choice of management options. Another common problem is the communication by stock assessment scientists of technical advice to non-technical managers and stakeholders. Frequent discussions among these three groups helps considerably but does not completely close the communication gap.

Therefore, Recommendation 2 is for stock assessment scientists to explore different ways of presenting quantitative results and to test their effectiveness with formal "user studies".

Recommendation 3 is that those presentation methods should include, at a minimum, the use of frequency format (e.g., "In 7 out of 10 situations like this, ..." instead of "The probability is 0.7 that ..."). Cognitive psychologists have found the frequency format to be more effective, and other researchers have shown serious problems with the IPCC's "likelihood" scales. However, IPCC-like statements of confidence that reflect the strength of evidence and level of agreement among experts about that evidence may be a useful added part of stock assessment advice. Interactive Shiny[5] apps may also be beneficial if they allow users to visually explore trade-offs and effects of different management actions.

Current quantitative fish stock assessment models are generally quite advanced at considering various uncertainties. Recommendation 4 is that such models should include not only observation error and high-frequency, year-to-year natural variability, but also low-frequency, non-stationarity in parameters (i.e., changing mean or variance over time), structural uncertainty, and outcome uncertainty. The latter refers to the difference between management targets and actual outcomes. That difference has been shown in several cases to be so large that it swamps attempts to reduce other types of uncertainty and can affect the rank order of management options.

Recommendation 5 is therefore to empirically estimate outcome uncertainty (both its imprecision and bias) and include it in stock assessment models.

[5] https://www.shinyapps.io/

The frequent tendency to make stock assessment models more complex should be tempered by Recommendation 6, drawn from a quote from Morgan and Henrion (1990), "A model should be as simple as possible, but no simpler than necessary."

Recommendation 7 recognizes that scientists may need to conduct sensitivity analyses with models of various levels of complexity to determine whether more complex ones affect the rank order of management options or research priorities.

In that context, Recommendation 8 is to conduct formal "Value of Information" (VOI) analyses to determine whether any proposed change in data-collection procedures, frequency of stock assessments, changes in model structure, etc. would be worth the additional cost. Such VOI analyses would be relatively straightforward for DFO's stock assessment scientists to conduct, given their high level of expertise in simulation modelling and Management Strategy Evaluation.

During the workshop, we heard that 50% of about 175 DFO stock assessments did not mention the effects of environmental variables, which was surprising given the well-documented effects of both physical and biological variables elsewhere. This may be a result of insufficient environmental data at the appropriate spatial or temporal scale, in which case Recommendation 9 is to request support to gather environmental data, analyze it, and include it in models where appropriate. Recommendation 10: In the absence of such new data, proxies or examples from elsewhere could form the basis of "What if..." statements in advice documents about potential effects of environmental variables. Only two participants in this workshop were aware of the U.S. NOAA/NMFS National Ecosystem Modelling Workshops (NEMoW), so Recommendation 11 is to investigate the four workshop reports from 2008, 2010, 2014, and 2017 (Townsend et al. 2008, 2014, 2017; Link et al. 2010). These proceedings describe many useful topics about management applications of ecosystem models.

Finally, risk management frequently requires fisheries managers to make difficult trade-off decisions between placing priority on long-term biological conservation objectives and short-term social and economic objectives. In their advice to managers, stock assessment scientists explicitly quantify and consider numerous sources of uncertainty and report the effects of those uncertainties. This practice is well justified and is now expected by managers. In contrast, there usually are few, if any, uncertainties stated about the social and economic indicators that are provided to managers. This is an unacceptable double standard; it is hard to believe that there are not also numerous large uncertainties in forecasts of effects of management options on our highly complex human systems. In this unbalanced situation, fisheries managers, either subconsciously or consciously, may tend to down-weight biological stock assessment advice relative to the social and economic indicators that have omitted uncertainties. Recommendation 12 therefore simply asks fisheries managers to apply the same rigorous standards about considering uncertainties to social and economic advice as they do to stock assessment advice.

STOCK SUMMARY CONCLUSIONS

It was clear that the participants in the Stock Summaries section of the workshop supported a standardized approach to Canadian Fish Stock Summaries produced by DFO. The regional and plenary presentations were also in favour of the original principles for Science Sector advice discussed during the workshop:

- Peer-review of stock assessments and recommended management measures,
- Reproducibility of scientific analyses, stock assessments and management advice, and
- Consistent communication of results that clearly links the science advice to legal compliance and the preservation of policy intent.

Generally, participants of the workshop approved of the suite of metrics presented in the original fish stock template based on the New Zealand stock summary. There was a feeling however, that a database structure that housed all the Science (and potentially management) information could be used to generate outputs that would suit a variety of needs (SAR reporting, audits, etc.). A template with a common “look and feel” using a subset of the metrics for fish stocks would be a valuable resource across the department.

To this end, we present a draft Canadian Fish Stock Summary report template for further development; the primary purpose of the template is to summarize information on the status of managed fish stocks. When completed, this template would include status determination along with the scientific evidence that supports these determinations. Report elements include, biological information important to stock dynamics, graphical representations of the main stock and fishery monitoring information, reference points, and where possible stock prognosis. Key references used to support the stock status report would be listed should the scientific details be required by interested parties.

Increasingly, the implementation of the Fish Stocks provisions of the revised *Fisheries Act* will require DFO to provide documentation for stocks prescribed under regulations. Standardized reports would be relevant across the Department by providing a single location for stock status determinations and could form part of the evidence base for prescribed stocks. Ideally, production of stock summaries would be as automated as possible by archiving information drawn from stock assessments and the literature as “derived data” in a database. Such a database would allow tracking of stock summary information over time as well as the potential for flexible reporting in addition to stock summaries to serve a variety of purposes and audiences.

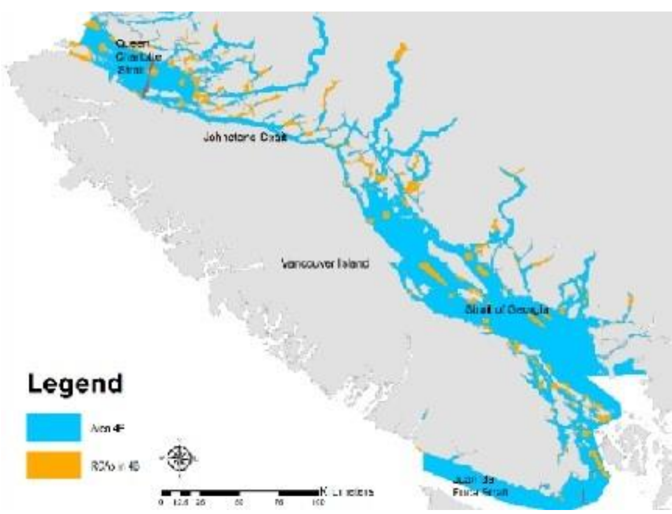
Example template for stock status

Canadian Fish Stock Status 2021

Yelloweye Rockfish, Inside waters

2022-02-15

Last Assessment or Update Year: 2011	Stock Status in Relation to Limit Reference Point: Critical
Sustainability Survey for Fisheries: 2019 Listed	Fish Stocks Provisions Status: Proposed for Batch 1
Species: *Sebastes ruberrimus* Common names: en - yelloweye rockfish, fr - sébaste aux yeux jaunes	Region: science – Pacific, management – Pacific Co-management: No

Description:	Stock Management Area
Dorsal spines (total): 13; Dorsal soft rays (total): 13-16; Anal spines: 3; Anal soft rays: 5 - 8. Head spines very strong to strong - nasal, preocular, supraocular, postocular, tympanic and parietal spines present, coronal and nuchal spines usually present. Raspy ridges on older fish. Caudal fin rounded. Orange red to orange yellow in color; eye bright yellow; fins may have black tips; adults usually with light to white stripe on lateral line; juveniles with 2 light stripes, one on lateral line and a shorter one below lateral line	

Biology : Occur in rocky reefs and boulder fields, the young found in shallower regions. Feed on fishes and crustaceans. Viviparous. Sold as fillets. Aggregate Stock Structure: No. Genetic structure suggests a putative population in the Georgia Basin separated from a panmictic population in the outer coast of BC.	

Reference Points

Limit Reference Point: LRP = 1,293 t Biomass estimate is 60 % of the LRP LRP calculated as 0.4 BMSY = 0.2 B0	Upper Stock Reference: USR = 2,586 t Biomass estimate is 30 % of the USR USR calculated as 0.8 BMSY = 0.4 B0
Limit Fishing Rate (Removal Reference):	Target Reference Point:

Stock Assessment

Assessment Type: Full Quantitative stock Assessment	Assessment Method:
Assessment Frequency: 5 years	Assessment Model:

Assessment History:

Year	Full Assessment / Update	Landings	TAC		

Next Scheduled Assessment:

Stock and Fishery Trends:

[Catch]
[Biomass]
[Fishing Mortality]
[Recruitment]

Management

Management Plan (IFMP):

Harvest Control Rule (HCR)	<brief description, link or citation to description>
Quantitative Input/ Output Controls	<e.g., effort or catch limit-controlled fishery>
Qualitative Input Controls	<e.g., seasonal and temporal closures, gear restrictions>
Quantitative Output Controls	<e.g., age, size or sex limits>

Rebuilding Plan

Probable Causes of the Stock's Decline:

Measureable Objectives Aimed at Rebuilding the Stock

Rebuilding Target and Timeline:	Additional Measureable Objectives and Timelines:

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Latest SAR or SR: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2011/2011_084-eng.html

Latest full assessment: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2011/2011_084-eng.html

LRP development: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2011/2011_129-eng.html

USR development: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2011/2011_129-eng.html

IMFP: http://waves-vagues.dfo-mpo.gc.ca/Library/40765167.pdf

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APPENDICES

APPENDIX 1 – PARTICIPANT LIST

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APPENDIX 2 – TERMS OF REFERENCE (ENGLISH)

Part I Uncertainty and risk in fisheries science advice

Context

Risk management is the act of making a decision in the face of uncertainty while knowing that undesirable outcomes may result from the action. Decisions on natural resource management in DFO, including fisheries, are a form of risk management. When a management decision is made on fisheries exploitation there are some assumptions about a desired objective for a stock, the degree of impact of the activity on the stock and how that activity will affect the probability of achieving the objective. Objectives may be implicit (e.g. maintaining status quo is often one), or involve explicit setting of targets and avoidance points. Impact evaluation carries some level of uncertainty depending on the available data and knowledge and the type of assessment. The probability of achieving the objective, given the magnitude of the allowed impact and associated uncertainty, is risk. Despite the fact that risk management is inherent to all resource management decisions in the Department, there is little guidance to aid consistent risk management or for how scientists should provide risk based options to managers.

The precautionary approach (PA) (DFO 2006) is a risk management framework for fisheries in DFO. The PA includes objectives and decision rules but it does not clearly articulate standards for managing risk that should be associated with certain objectives or avoidance points. For example, given a biomass limit reference point (Blim) in the PA and a stock somewhere above that point, decisions must be made on allowable catch such that there is a low probability that their decisions will push the stock below Blim. Standards for low probabilities of undesirable outcomes exist but vary among jurisdictions. In ICES, for example, this low probability is set as 5% each year, while in Australia, a 10% (1 in 10 year) probability is used. There is no strict standard in Canada. As a result we potentially have inconsistent risk standards in providing advice for different stocks, such that higher risk of breaching the limit reference point may implicitly be allowed for some stocks but lower risk for others.

Scientists often find it challenging to either convert uncertainty into risk, or to communicate risk in advice to aid decision makers. A variety of methods exist for clearly articulating risk associated with a range of management options but these are used inconsistently in the department. It is also never clearly evaluated nor articulated how incremental risk can change for an identical decision depending on the available data and knowledge, the type of assessment, and the processes that may be acting on the resource. For example an ecosystem factor such as increasing predator abundance can add an incremental increase in the risk of decisions for commercial exploitation of a prey species. Likewise, climate change can lead to an incremental change in risk for management of a particular resource compared to the same risk evaluated under the assumption of no climate forcing. Describing risk incrementally can aid in communicating risk to managers.

Our goal for this workshop is to explore uncertainty and risk evaluation and communication in fisheries science and resource management, with the objective to move towards a common understanding of risk and risk management standards that should eventually lead to clearer risk-based advice to managers.

Objectives

- Elucidate how decision-making in fisheries is already (often implicitly) risk management
- Understand the PA as a risk management framework (PCO 2003)
- Understand the relationship between uncertainty and risk, source of uncertainty and incremental risk

- Explore international practices on estimating and communicating uncertainty and risk (See Annex 2)
- Communicate the trade-offs between level of exploitation, time, risk and the objective
- Evaluate and communicate how the uncertainties associated with available data and knowledge incrementally impact science advice
- How much additional uncertainty is enough uncertainty to include and incremental risks
- Demonstrate how some fisheries assessment advice can often be communicated in purely risk terms
- Explore standards for risk management used in other jurisdictions and in other domains (see Annex 1)
- Discuss qualitative and semi-quantitative risk-based methods and how different kinds of knowledge can be integrated into risk-based frameworks
- Develop a consistent qualitative word set associated with levels of uncertainty (e.g. "very certain")
- Suggest a roadmap for development of documents and tools to aid uptake of consistent uncertainty assessment and risk management frameworks in DFO.

Format

- Structured discussions around topics related to meeting objectives
- Presentation of working papers on key issues, subject to review
- Presentation of examples of uncertainty and risk-based advice in fisheries. Possibly employing a "before and after" approach with Canadian examples
- Presentations from invited external experts
- Breakout groups around particular topics and overview text resulting from this and presentation in plenary.

Expected Products

- A proceedings report with recommendations
- Possibly an online repository of methods, standards

Participation

- DFO Science from all regions (including Canadian Science Advisory Secretariat)
- DFO Fisheries Management and Policy sectors
- Invited external experts
- 30-40 participants are expected.

Part II Standardized stock summaries

Context

Sustainable fisheries depend on several steps taken by the responsible agency, DFO in this case:

- quality input data
- quality assessment methods and analyses
- reproducibility of scientific analyses
- peer review of assessments and analyses
- derivation of fisheries advice consistent with the analysis and which outlines the implications of particular management decisions
- effective communication of all of the above.

This is all done against a backdrop of particular legislative frameworks and policies consistent with those frameworks.

Canada's legislation for mandating sustainable fisheries, he *Fisheries Act*, is currently undergoing substantive proposed changes (by means of Bill C-68) that are likely to result in repercussions for all the above steps. At the same time, the Canadian Science Advisory Secretariat has been undergoing internal review for at least a year and the system is currently amenable to changes and improvement. These changes should help to meet the challenges of the proposed changes to the *Fisheries Act* and to update the science advice process in DFO supporting new ways of doing science, facilitating new management paradigms, and also streamlining how scientific information and advice are reported and communicated to an increasingly diverse and informed stakeholder and manager group.

This particular workshop is focusing on the idea of a stock assessment summary sheet. This is not a novel idea and is already operationalised in jurisdictions such as New Zealand, NAFO and ICES. The stock summary sheets in these jurisdictions condense key components of the large science development and advisory process in a standardised format. So, for example, these sheets contain current stock status in relation to reference points, among other items. Many other key aspects of the assessment process can be included in these sheets, such as a description of key scientific uncertainties (what is not known but is impactful to the advice), and a plan to reduce those uncertainties. The common look and feel of such summary sheets can be a asset in the communication of the science and as a result it should lead to more transparent and consistent decision-making for managers.

The anticipated role of a National Fisheries Science Working Group (NFSWG, established April 2019) includes the development of national operational science guidelines, such as those related to stock rebuilding, data-poor contexts, or management strategy evaluation (MSE). Such guidelines may mean that, among other things, science advice and reporting will need to be standardized. Standardization can help demonstrate that an acceptable practice is being followed, regardless of the state of data or model poverty. Additionally, the recently launched Ecosystem Approach to Fisheries Management working group (EAFM-WG) is also making headway to operationally include environmental and ecosystem information in the stock assessment and advisory process. It is important to note that ecosystem considerations (*environmental conditions*) are part of the Fish Stocks provisions of Bill C-68. Standardised approaches reflected in guidelines need to also therefore go beyond traditional assessment output, reporting and advice but must be able to accommodate new paradigms such as MSE and an ecosystem approach to fisheries management.

Objectives

- Debate the strengths and weaknesses of the present reporting system (process and documentation) for fisheries science information and advice, and how a stock summary sheet may be able to fill some of the current issues
- Scrutinize stock summary sheets developed in other jurisdictions for their strengths, weaknesses and applicability to the Canadian context
- Develop a rough outline describing the essential elements of a stock summary sheet
- Discuss tools for delivering on such a summary
- Develop a work-plan to bring a stock assessment summary sheet to fruition.

Format

- Presentations from DFO staff and invited experts on the process of delivering science and advice in Canada and elsewhere
- Presentations of stock summary sheets from other jurisdictions.

Expected products

- A skeleton example stock summary sheet
- A work-plan for further refining aspects of the stock summary sheet.

Participation

As in Part I of the workshop

APPENDIX 3 – WORKSHOP AGENDA

Part I – Risk Estimation and Communication

January 27-29, 2020

DAY 1 of 5: January 27		Presenter or Lead
9:00 am (30 min)	**Introductions** and icebreaker	Susan Thompson
9:30 am (15 min)	Review of agenda, objectives and deliverables	Chairs: Daniel Duplisea, Rob Kronlund
9:45 am (45 min)	**Presentation**: Francis and Shotton concepts of risk in fisheries	Rob Kronlund
10:30 am (15 min)	***HEALTH BREAK***	
10:45 am (20 min)	**Presentation**: The PA as a risk management framework: examples from many jurisdictions	Julie Marentette
11:05 am (20 min)	**Presentation**: How risk is considered in the ICES precautionary and MSY approaches	Daniel Ricard
11:25 am (35 min)	**Presentation**: How DFO policy and fisheries management sectors think about risk, risk management and what would be a useful kind of risk assessment	Marc Clemens, Amy Lebeau
12:00 PM (1 hr)	***LUNCH***	
1:00 pm (40 min)	**Presentation**: How the IPCC deals with risk (20-25 min) Substantive discussion on what we see as useful in the IPCC approach	Kendra Holt
1:40 pm (30 min)	**Presentation**: Risk equivalency, buffers and conditioning risk to various factors	Marie-Julie Roux
2:10 pm (20 min)	**Presentation**: Uncertainty in fisheries and including it in fisheries advice	Andy Edwards
2:30 pm (15 min)	***HEALTH BREAK***	
2:45 pm (20 min)	**Presentation**: Indigenous knowledge systems across Canada: insights for understanding diverse perspectives on risk	Steven Alexander
3:05 pm (1 hr)	**Presentations**: Risk applications	
	• Pacific salmon (15 min)	Ann-Marie Huang Carrie Holt
	• Arctic fisheries and climate change (15 min)	Xinhua Zhu
	• Groundfish management procedure framework (15 min)	Robyn Forrest, Sean Anderson
	• Risk-based management of scallop fisheries (15 min)	Jessica Sameoto
4:05 pm (45 min)	**Group discussion:** Presentations thus far, key points to emphasize in documentation. Ideas for follow-up/recommendations.	All (Chairs facilitating)
4:50 pm (25 min)	Prep for Day 2 breakout exercises: feedback on proposed topics, logistics	Daniel Duplisea

5:15 pm	***END OF DAY 1***	
Daily deliverable: • Participants have a shared understanding of concepts, considerations and challenges related to uncertainty and risk in fisheries assessment, advice and management based on global and domestic approaches and issues.		

DAY 2 of 5: January 28		**Presenter or Lead**
8:45 am (15 min)	Recap of Day 1 Review of Day 2 agenda and deliverables	Chairs
9:00 am (1 hr)	**Presentation**: Some considerations about stock/risk assessment, risk communication, and risk management	Randall Peterman
10:00 am (15 min)	***HEALTH BREAK***	
10:15 am (1 hr 15 min)	**Breakout exercise #1** • <u>Topic 1:</u> The other part of risk: costs and benefits. How can you bring this into the advice to managers, is it useful? • <u>Topic 2:</u> Congruence and differences between how MSE deals with risk and the standard paradigms for dealing with risk • <u>Topic 3:</u> What are we missing about risk ideas in fisheries that have been well developed in other fields • <u>Topic 4:</u> Hobday 2011 ERAEF - possibilities for application in Canada • Other topics?	All (NCR facilitating) 1 topic/group x 4-6 groups **Use the flip charts to record your results.**
11:30 AM (1 hr)	***LUNCH***	
12:30 pm (45 min)	**Group Reports for Exercise #1** **5 min/group** followed by general discussion	Rapporteurs + All (Chairs facilitating)
1:15 pm (1 hr 45 min; *health break when needed*)	**Breakout Exercise #2** • <u>Topic 5:</u> Comparative risk levels: look in ICES, NZ, Canada, elsewhere and develop an example of risk levels that would be compatible with international norms for various well known processes. A proposal for DFO. • <u>Topic 6:</u> IPCC risk language: develop a language set that communicates risk levels useable in fisheries • <u>Topic 7:</u> Risk communication tools, language • <u>Topic 8:</u> Risk evaluation over the data and knowledge availability continuum, and combining multiple models • Other topics?	All (NCR facilitating) 1 topic/group x 4-6 groups **Use the flip charts to record your results.**
3:00 pm (15 min)	***HEALTH BREAK***	

3:15 pm (1 hr 15 min)	**Group Reports for Exercise #2** **10 min/group** followed by general discussion	Rapporteurs + All (Chairs facilitating)
4:30 pm (30 min)	Prep for Day 3 breakout exercises	Daniel Duplisea
5:00 pm	***SOCIAL GATHERING***	
Daily deliverable: • List of recommendations from the various breakout exercise topics.		

DAY 3 of 5: January 29		**Presenter or Lead**
8:45 am (15 min)	Recap of Day 2 Review of Day 3 agenda and deliverables	Chairs
9:00 am (30 min)	**Presentation**: Black swans and do we need to consider them in risk-based fisheries advice and management?	Sean Anderson
9:30 am (2 hr; *health break when needed*)	**Breakout Exercise #3**: Case study: given a dataset, derive useful risk-based advice or outline process to develop risk-based advice. • Discussion (1 hr) • Report writing (1 hr)	All (6 groups, NCR facilitating) **Use the flip charts to record your results.**
11:30 PM (1 hr)	***LUNCH***	
12:30 pm (1 hr 15 min)	**Group Reports for Exercise #3**; provide a written report as well **10 min/group** followed by general discussion	Rapporteurs + All (Chairs facilitating)
1:45 pm (15 min)	***HEALTH BREAK***	
2:00 pm (30 min)	**External Expert Review**: Observations, commentary and recommendations.	Randall Peterman
2:30 pm (45 min)	**Breakout Exercise #4**: Roadmap for the development of risk-based advice by DFO Science	All (6 groups, NCR facilitating) **Use the flip charts to record your results.**
3:15 pm (15 min)	***HEALTH BREAK***	
3:30 pm (45 min)	**Group Reports for Exercise #4** **5 min/group** followed by general discussion	Rapporteurs + All (Chairs facilitating)

4:15 pm (15 min)	Recap of Workshop Part I Write-up, assignment of tasks, timelines, desired outcomes, follow-up and recommendations, next steps	Chairs
4:30 pm (30 min)	**Presentations**: Transition to Workshop Part II	
	• Fish Stocks Provisions: Record of Evidence (15 min)	Amy Lebeau
	• Modern collaborative tools for automatically generating standardized documents (15 min)	Andy Edwards
5:00 pm	***END OF DAY 3***	
Daily deliverables: • Detailed reports of risk-based advice (or the steps required to develop risk-based advice) for managers according to differences in data and knowledge availability. • Roadmap for the development of risk-based advice by DFO Science. • List of action items and next steps arising from workshop, including roles, responsibilities and timelines regarding tasks, writing assignments and products.		

Part II – Stock Summaries

January 30-31, 2020

DAY 4 of 5: January 30		**Presenter or Lead**
8:45 am (15 min)	**Introductions** for new participants, recap of Part I outcomes	Chairs: A.R. Kronlund, D. Duplisea
9:00 am (30 min)	**Presentation**: Introduction to Stock Summaries	A.R. Kronlund, J.R. Marentette
9:30 am (30 min)	**Regional Summaries of Homework Findings**: Maritimes, Gulf, Quebec, Central and Arctic, Pacific, Newfoundland, NCR	Regional representatives (~15 minutes per Region)
10:00 am **(15 min)**	***HEALTH BREAK***	
10:15 am (1 hr)	Regional Summaries cont'd.	Regional representatives
11:15 pm (45 min)	**Breakout Exercise #5** – Principles for DFO Stock Summaries ***Purpose***: Identify principles for a DFO stock summary. Possible principles (you are not restricted to this list): • Succinct – avoids drowning in details and burying the lede; • Flexible – accommodates a variety of life history types, data poor to rich; • Focused – the elements are a minimum set to inform a decision; • Clear – documented, consistently applied, reproducible; and • Versatile – underlying metadata could be repackaged.	All (6 groups, NCR facilitating) **Use the flip charts to record your results.**

	Output: Provide a prioritized list of principles (1-5, plus any additional principles) and describe how to operationalize the **top 2** principles.	
12:00 pm **(1 hr)**	***LUNCH***	
1:00 pm (45 min)	**Group Reports for Exercise #5** **5 min/group** followed by general discussion	Rapporteurs + All (Chairs facilitating)
1:45 pm (30 min)	**Presentation**: Stock Summary information for ecosystem considerations	P. Pepin
2:15 pm **(15 min)**	***HEALTH BREAK***	
2:30 pm (45 min)	**Breakout Exercise #6** – Cross Jurisdictional Comparison ***Purpose***: Contrast an ICES stock summary with the New Zealand “homework” template. Consult the “basis for advice” document for ICES if necessary. Focus on the following elements: • Stock trend over time and prognosis; • Stock status and exploitation status (reference points); • Issues relevant for assessment (key drivers of dynamics); and • Uncertainty and risk communication. ***Outputs***: Report on the following: 1. Identify which stock summary best captures the elements. 2. What features do you really like? What features do you dislike? 3. Are there situations in Canada that do not fit either the ICES or New Zealand stock summary? 4. Do the ICES and New Zealand summaries meet the principles from Breakout Exercise #1?	All (6 groups, NCR facilitating) Note that 3 types of ICES summaries will be distributed but each group will have only 1 type: • Tier 1 “data rich” • Tier 3 “survey-based index assessment” • Tier 5: “landings only, low information” **Use the flip charts to record your results.**
3:15 pm **(15 min)**	***HEALTH BREAK***	
3:30 pm (45 min)	**Group Reports for Exercise #6** **5 min/group** followed by general discussion	Rapporteurs + All (Chairs facilitating)
4:15 pm (15 min)	**Presentation**: Science Outputs, Stock Summaries and the Record of Evidence	J.R. Marentette
4:30 pm (30 min)	**Prep for Breakout Exercise #7:** Stock Summary “*Deep Dive*” ***Purpose***: Critical review of “homework” stock summary template. Each group will address issues drawn from experience with the homework template for assigned topics (e.g., B: Reference points, G: Status).	All (6 groups, NCR facilitating)
5:00 pm	***END OF DAY 4***	Chairs

Daily Deliverables:

- List of principles for stock summaries.
- Identification of preferred elements based on a cross-jurisdictional comparison.
- The Good, the Bad, and the Ugly. What works, what doesn't in stock summaries.

DAY 5 of 5: January 31, 2020		**Presenter or Lead**
8:45 am (15 min)	Recap of Day 4, remaining issues, deliverables	Chairs
9:00 am (1 hr)	**Breakout Exercise #7:** Stock Summary "*Deep Dive*" ***Purpose***: Critical review of "homework" stock summary template Address the specific issues assigned to your group to identify the Good, Bad, and Ugly. A list of issues will be supplied for your group. Please add your suggestions and identify solutions.	All (6 groups, NCR facilitating) **Use the flip charts to record your results.**
10:00 am **(15 min)**	***HEALTH BREAK***	
10:15 am (1 hr 15 min)	**Group Reports from Exercise #7**. Report from groups on Topics A-J. Good, bad and ugly of stock summary, gap analysis, proposed solutions. **10 min/group** followed by general discussion	Rapporteur + All (Chairs facilitating)
11:30 am (30 min)	**Group Discussion:** CSAS Renewal and more ***Purpose***: Update from the CSAS office on consultations related to "CSAS renewal". (5-10 min) • Discuss if and how stock summary concepts could be used for CSAS products. • How to minimize work repackaging Science outputs for CSAS, the Fisheries Sustainability Survey, the Record of Evidence, audits, *ad hoc* requests. ***Outputs***: Ideas and recommendations from discussion.	E. Couture All (Chairs facilitating)
12:00 pm **(1 hr)**	***LUNCH***	
1:00 pm (30 min)	**External Expert Review**: Observations, commentary and recommendations.	R. Peterman
1:30 pm (45 min)	**Group Discussion**: Standardization and adaptation ***Purpose***: Consider the following questions: • How to include all life history types? Are there special cases? • How do we deal with multiple models, MSE, data-poor cases? • How can we limit the number of stock summary types? • What is required to support a departure from a common format?	All (Chairs facilitating)

2:15 pm (30 min)	**Group Recommendations**: Input to NFSWG and NOG • Is a common stock summary worth pursuing? • Could a stock summary be a SAR substitute or major component? • Process for defining a template and supporting documentation? • Should we pursue document automation (database to document)?	All (Chairs facilitating)
2:45 pm (15 min)	Closing remarks	Chairs
3:00 pm	***ADJOURN***	
Daily Deliverables: • List of recommendations for development of stock summaries and applications.		

APPENDIX 4 – PRE-WORKSHOP EXERCISE: A STOCK ~~SUMMARY~~SUMMARY

Context

Why?

The pre-workshop exercise described below is intended to illustrate the scope of challenges likely to be encountered in developing standardized stock summaries for all Regions. The template provided should be considered an experiment, and should not be regarded as an endorsed format. Completion of the exercise and presentation of the results at the January 27-31, 2020 TESA workshop will help orient participants to some of the issues, stimulate discussion about priorities, and allow participants to communicate challenges based on their experience. Workshop participants will consider the question of how the defense of Science Sector advice can be supported through consistent reporting of key elements related to Fish Stocks provisions and the PA Policy. At the workshop, we will discuss the challenges that emerge and develop recommendations for their resolution. Some issues may be resolved at the workshop, others will require subsequent research.

What?

We are asking that TESA Leads in each Region coordinate this exercise. Participants are requested to choose stocks within each Region that illustrate a variety of situations so that broad commonalities and exceptions can be diagnosed. Try to include stocks that reflect the following attributes:

- A range of species groups (e.g., groundfishes, invertebrates, pelagics, marine mammals, anadromous species);
- A range of data and model poverty (rich to poor); and
- A range of perceived stock status (rebuilding candidates to stocks near historical highs).

There are two types of outputs requested for each example stock:

c) A "*Stock Summary"* completed to the extent possible (*one stock summary per participant*); and

d) *"Evaluation notes"* (1-page, point form) that describe how well the "source" documents captured the requested information. Source documents may include CSAS Research Documents, Science Advisory Reports, Science Responses or other documents. As you complete the exercise, please note criticisms and pitfalls, and provide suggestions for an improved approach. Was it easy to find the information? What was missing? What tables or figures were particularly useful? (*one evaluation page per participant based on their Stock Summary*).

A third output is requested to synthesize results from each Region:

e) A "*Situation Report*" that summarizes the benefits and key challenges encountered by your Region when completing the *Stock Summary* template (one *Situation Report* per Region). Each TESA Lead or alternate will present the report at the workshop.

How?

Instructions for completing the exercise are included below:

a) *Stock Summary*

The draft template (*draftStockSummaryTemplateVer1.1-06Sep19.doc*) provided is a modification of the New Zealand format (Fisheries New Zealand 2018). Elements germane to

Canada under the Fish Stocks provisions and the PA Policy (DFO 2009) are included. The instructions (*draftInstructionsStockSummary-06Sep19.doc*) contain guidance on the contents of most of the fields in the table. At this early stage the guidance is not intended to be rigid, and great ideas will be greedily adopted. Each table of the template has a alphabetic letter (A-J) and each data field (row) is numbered sequentially within each table. The letter and number combination can be used to refer to the instructions (e.g., B1 Limit Reference Point in the table matches B1 in the instructions). Examples from a Canadian fishery (courtesy of Brian Healey) and Fisheries New Zealand (2018) are appended for interest and inspiration. Participants should consider this a “prototyping” exercise to assist the discussion and expose the types of problems in reporting that are likely to be encountered (i.e., use your judgement in determining the level of detail needed for the workshop).

b) *Evaluation Notes*

There is no set format for the 1-page of notes requested. This is your chance to identify information was easily located, or not. You can point out where the situation for your stock does not fit well into the template (and if you can, suggest a resolution!). Note any essential information that the template omits, and suggest ways improve the information captured under any template item. Include any examples from other stocks or jurisdictions that you feel would help improve communication (alright, you can use both sides of the page…).

c) *Situation Report*

A representative from each Region will be asked to provide a 15-20 minute presentation at the workshop to report the results of the exercise, highlighting elements high on the “worry list” for meeting obligations of the Fish Stocks provisions, PA Policy intent and clear communication of the information. This should be a synthesis of Regional experience with the stock summary exercise, not a re-iteration of the results for each stock (the *Evaluation Notes* serve that purpose). Please try to confine the presentation to a 15-20 minute length. Suggestions for topics and questions to address are included in a presentation template (*draftSitRepSummary-09Sep19.ppt*).

<u>Stock Summary Instructions</u>

General Instructions

Everything included in the Stock Summary table should be derived from the most recent assessment or update for your chosen stock. No new information should be presented in the summary that was not encompassed in the main text of the CSAS Research Document, Science Advisory Report, or Science Response. One Stock Summary should be completed for each assessed stock. Do not aggregate stocks or summarize fisheries on multiple stocks. In all cases, use N/A if information for the data field is not available. Red text in the template provide options for the entry – pick one option. If no suitable option exists, then insert something suitable. Blue text provides examples of how the table might be completed (the example text is not from a single stock). Where text appears as <*my text*>, replace as appropriate, e.g., <*My fish stock*> could be replaced with “Pacific Cod (*Gadus macrophalus*) in Major Areas 3CD”.

The PA Policy provisional reference points based on Maximum Sustainable Yield (MSY) have been used for example purposes. The data support for MSY-statistics is often not available; proxies can be applied under the PA Policy and may be the norm rather than exception, particularly as data poverty increases.

Probabilities. Where probabilities are used in qualifying a statement regarding the status of the stock in relation to limit, target, or other threshold reference levels, the following probability categories and associated verbal descriptions are to be used (DFO 2009, Annex 2):

Probability	Description
Less than 5%	Very low
5% - 25%	Low
25% - 50%	Moderate
~50%	Neutral
50%-75%	Moderately High
75%-95%	High
>95%	Very High

Probability categories and associated descriptions should relate to the probability of being “at or above” biomass targets (or “at or below” fishing intensity targets if these are used), below biomass limits, and above overfishing thresholds. Note, however, that the descriptions and associated probabilities should be superimposed with the belief about the extent to which the model fully specifies the probabilities.

NOTE: The source of the DFO risk table (DFO 2009, Annex 2) is not cited in the PA Policy. There is a need to review the risk (probability) categories with the view to adopting prevailing best practice in fisheries science. For example, New Zealand is following the IPCC (2007) designations listed in the following table; the descriptions provide a different perspective than those used by the PA Policy:

Probability	Description
> 99 %	Virtually Certain
> 90 %	Very Likely
> 60 %	Likely
40–60 %	About as Likely as Not
< 40 %	Unlikely
< 10 %	Very Unlikely
< 1 %	Exceptionally Unlikely

Notation for this document includes (spawning) biomass (*B*), fishing mortality (*F*), Maximum Sustainable Yield (MSY), limit reference point (LRP), upper stock reference (USR), target reference point (TRP), and removal rate (RR).

A STOCK DESCRIPTION

1. **Fish Stock Name**. Name of assessed fish stock (e.g., Pacific Cod (*Gadus macrocephalus*) in Major Areas 3CD).
2. **Stock Structure Assumptions/Basis**. Summarize the current assumptions regarding the stock structure and distribution of the stocks being reported. Where the assessed stock distribution differs from the stock defined for management, an explanation must be provided of how the assessed stock relates to the managed stock.

    NOTE: Stock structure is a key consideration for assessment, and often a high consequence source of uncertainty. Under the Fish Stocks provisions, there will be legal implications of associating a Limit Reference Point with the “stock”. Thus, the basis for stock definition and relationship to the LRP structure and distribution will need to be clearly defined and supported to the extent possible.

3. **Assessment Approach**. Define the assessment approach. *Choose one of the following*: Data-poor (indicators), Base case stock assessment, Model ensemble, MSE, Other (specify).

B REFERENCE POINTS

Where biological reference points and/or management targets have not been established, it is suggested that a limit reference point of $0.4B_{MSY}$ or proxy and limit fishing rate of F_{MSY} or proxy be adopted, i.e., the provisional choices specified in the PA Policy. The limit fishing rate will be considered an *overfishing* threshold. Overfishing thresholds can be expressed in terms of fishing mortality, exploitation rates, or other valid measures of fishing intensity. When agreed reference points have not been established, stock status may be reported against interim reference points that depart from the provisional reference points provided there is supporting rationale, e.g., an agreed upon low historical biomass to be avoided, empirical evidence of serious harm, a replacement fishing mortality and associated biomass as a threshold for recruitment overfishing (Sissenwine and Shepherd 1987), etc.). Such choices may subsequently be adopted as agreed-upon reference points.

Reporting stock status against reference points requires agreement on (a) the model used as a base case for the assessment, (b) the weighting of models in an ensemble approach, or (c) the weighting of operating models used in an MSE process. In general, ranges or confidence intervals should not be included in the table, but should be included in the Research Document when available. Only where more than one equally plausible model case exists, and agreement cannot be reached on a single base case, ensemble, or weighting of operating models, should multiple model cases be reported. This should still be done simply and concisely (e.g., median results only).

1. **Limit Reference Point (LRP)**. A LRP is a threshold to an undesirable stock state, to be avoided with high probability (DFO 2009) and can be based on biomass (abundance) or fishing rate (see B3 below). Other metrics are possible (e.g., spatial limit reference points, life-history based) under the PA Policy (2009).
2. **Basis for LRP**. What is the rationale for the choice of LRP? Policy, international agreement, theoretical threshold to serious harm (e.g., recruitment levels below replacement levels), empirical evidence of serious harm, historical low biomass)?
3. **Limit Fishing Rate (Removal Reference)**. In 2013, the New Zealand summary was modified to require scientific working groups to make a determination about whether overfishing is occurring, something not currently done in Canada, but routinely done in other jurisdictions (e.g., Australia, USA). If the limit fishing rate is exceeded (e.g., $F > F_{MSY}$), then overfishing is occurring.
4. **Basis for Limit Fishing Rate**. What is the rationale for the choice of Limit Fishing Rate? Policy, international agreement, theoretical threshold to serious harm (e.g., recruitment levels below replacement levels), empirical evidence of serious harm, historical low biomass).
5. **Upper Stock Reference (USR)**.
6. **Basis for USR**. What is the rationale for the choice of USR?

NOTE: In contrast to the LRP, the USR is not enshrined in law under the Fish Stocks provisions of the revised *Fisheries Act*. From a biological perspective, the LRP is argued to represent a threshold to “serious harm” (Shelton and Rice 2002), despite the difficulty of identifying that threshold *a priori*; the USR has no such basis as a biological reference point. Regardless, completeness of PA Frameworks, including the USR, may be part of the criteria for determining a stock is listed under regulations. Two roles are attributed to the Upper Stock Reference in policy (DFO 2009):

“… the USR can perform two functions. First, in accordance with SAR 2006-023 the USR is the stock level threshold below which removals must be progressively reduced in order to avoid reaching the LRP. For this reason, under this framework, the USR, at minimum, must be set at an appropriate distance above the LRP to provide sufficient opportunity for the management system to recognize a declining stock status and sufficient time for management actions to have effect. Secondly, the USR can be a target reference point (TRP) determined by productivity objectives for the stock, broader biological considerations, and social and economic objectives for the fishery.”

In the first function the USR is considered an operational control point where management action is taken (reduction of removals) to avoid a limit with high probability. For the second function, the USR is equated with a target reference point to be achieved with some desired certainty. However, it cannot serve both roles simultaneously, since adjusting the USR as a control point to avoid the LRP is likely to be in conflict to an objective to achieve the desired certainty of exceeding the USR as a target reference point (and in any case conflates objectives with tactics designed to achieve the objectives). This is an example of the type of issue that the NFSWG could resolve when defining an acceptable standard of practice via national guidelines.

7. **Target Reference Point (TRP)**. A target reference point represents a desirable state for the stock and fishery, usually based on socio-economic considerations but often considered to be consistent with $B > B_{MSY}$).
8. **Basis for TRP**. What is the rationale for the choice of TRP?
9. **Conservation objectives (biological).** State the (measurable) conservation objectives for the stock that incorporate the reference points. Measureable objectives include a desired outcome (e.g., spawning biomass > $0.4B_{MSY}$), a probability of achieving that outcome (e.g., 95%) and a time-frame for evaluation (e.g., 20 years). If no measurable objective has been defined, state the goal or report N/A. If the stock is subject to a rebuilding plan, what are the conservation objectives for rebuilding?
10. **Fishery objectives (socio-economic)**. State the (measurable) socio-economic objectives for the stock and fishery. Measureable objectives include a desired outcome (e.g., spawning biomass > $0.4B_{MSY}$), a probability of achieving that outcomes (e.g., 95%) and a time-frame for evaluation (e.g., 20 years). If no measurable objective has been defined, state the goal or report N/A. If the stock is subject to a rebuilding plan, what are the fishery objectives for rebuilding?
11. **Evaluation** (of management procedure performance against objectives, where a management procedure is defined as the data, assessment method, and harvest decision rule used to provide advice). *Choose one of the following*: N/A, Not conducted, Retrospective (*n* years), Prospective (feedback simulation).

C DATA

NOTE: The science **Information quality** rankings can be subjectively assigned for this exercise, however New Zealand follows the Research and Science Information Standard, approved in April 2011 (New Zealand Ministry of Fisheries 2011a). DFO Science Sector could consider whether to implement a standard that ranks the quality of research and science information used in support of fisheries management decisions:

1 - ***High Quality***. Information that has been subjected to rigorous science quality assurance and peer review processes as required by a defined standard, and substantially meets the key principles for science information quality. Such information can confidently be accorded a high weight in fisheries management decisions. An explanation is not required in the table for high quality information.

2 – ***Medium or Mixed Quality***. Information that has been subjected to some level of peer review against the requirements of a defined standard and has been found to have some shortcomings with regard to the key principles for science information quality, but is still useful for informing management decisions. Such information should be accompanied by a description of its shortcomings.

3 – ***Low Quality***. Information that has been subjected to peer review against the requirements of a defined standard but has substantially failed to meet the key principles for science information quality. Such information should be accompanied by a description of its shortcomings and should not be used to inform management decisions.

One of the key purposes of the science information quality ranking system is to inform fisheries managers and resource users of those datasets, analyses or models that are of such poor quality that they should not be used to make fisheries management decisions (i.e., those ranked as “3”). Uncertainty, which is inherent in all fisheries science outputs, should not by itself be used as a reason to score down an assessment output, unless it has not been properly considered or analysed, or if the uncertainty is so large as to render the results and conclusions meaningless. In the latter case, consideration should be given to rejecting the output. A ranking of 2 (medium or mixed quality) should only be used where there has been limited or inadequate peer review or the Working Group has mixed views on the validity of the outputs, but believes they are nevertheless of some use to fisheries management.

1. **Main data inputs**. Describe only the data inputs for the assessment, regardless of whether the assessment is model- or empirically-based. Where appropriate provide year ranges for time series. For example, “Research bottom trawl survey biomass index (1998-2018).”
2. **Data not used**. In most cases, the “Data not used” field can be filled in with “N/A”; it is primarily useful for specifying particular datasets that were considered but did not see use in an assessment because (a) they were of low quality and should not be used to inform fisheries management decisions, or (2) there is a state of model and time poverty that precluded their use.

D ASSESSMENT METHODOLOGY

1. **Assessment Type**.

> **NOTE**: Assessment Levels are to be assigned using expert opinion for this exercise; the categorization below is from Fisheries New Zealand (2018):
>
> 1 – ***Full Quantitative Stock assessment***. There is a reliable index of abundance and an assessment indicating status in relation to limits and targets.
>
> 2 – ***Partial Quantitative Stock Assessment***. An evaluation of agreed abundance indices (e.g., standardised CPUE, research survey biomass index, tagging series) or other appropriate fishery indicators (e.g., estimates of F (Z) based on catch-at-age) is available. Indices of abundance or fishing intensity have not been used in a full quantitative stock assessment to estimate stock or fishery status in relation to reference points.
>
> 3 – ***Qualitative Evaluation***. A fishery characterisation with evaluation of fishery trends (e.g., catch, effort, unstandardised CPUE, or length-frequency information) has been conducted but there is no agreed index of abundance.
>
> 4 – ***Low Information Evaluation***: There are only data on catch and total allowable catch, with no other fishery indicators.

2. **Assessment Method**. Describe assessment method, e.g., empirical abundance trends, surplus production model, delay-difference model, VPA, cohort model, statistical catch-at-age model, etc.
3. **Last Assessment Date**. Year of last assessment.
4. **Next Assessment Date**. Year of next assessment.
5. **Basis for Assessment Frequency**. Rationale for assessment frequency, noting any circumstances that might trigger an early assessment.
6. **Assessment Model(s) Presented**.
7. **Overall Assessment Quality Rank**. Use the Information Quality rankings provided under **C Data**.

8. **Changes to Model Assumptions and Structure**. The primary purpose of this section is to briefly identify only the most significant model changes that directly resulted in significant changes to results on the status of the stock concerned, and to briefly indicate the main effect of these changes. Details on model changes should be left in the main text of the Research Document.
9. **Major sources of Uncertainty**. List primary sources of uncertainty *in model assumptions*, or sources that led to selection of models in an ensemble, or rationale for operating model scenarios in an MSE process. Confine the sources of uncertainty to model assumptions, or to high priority uncertainties that need to be addressed when possible (i.e., where evidence exists to suggest a hypothesis).

E MANAGEMENT MEASURES

1. **Harvest Control Rule**. N/A or describe HCR, e.g., Segmented harvest control rule with precautionary ramp.
2. **Control Variable**. Catch, Effort, or?
3. **Spatial Closure(s)**. Note only those closure intended to reduce exposure of the stock to fishing effort or serve a specific biological purpose (e.g., protection of nest-guarding species, spawning habitat).
4. **Seasonal Closures(s)**.
5. **Size Limit**. State rationale for the size limit if applicable.
6. **Gear Restrictions**. State rationale for the size limit if applicable.
7. **Other**.

F HISTORICAL STOCK TRAJECTORY

This heading should be changed to reflect the graphs that are available to illustrate trends in biomass or fishing intensity (or proxies) and the current stock or fishery status. These might include:

- Estimated spawning biomass and catch as a function of year;
- Estimated recruitment deviations as a function of year;
- Phase plot of F/F_{limit} against B/B_{LRP}; or
- Estimates of time-varying parameters as a function of year.

NOTE: Development of national consistency would ideally result in a set of default figures suitable to context. There is unlikely to be a single set of figures that addresses all situations, but a finite set of choices is a desired outcome of a standard.

G STOCK STATUS

Probability categories and associated descriptions should relate to the probability of being “at or above” biomass targets (or “at or below” fishing intensity targets if these are used), below biomass limits, and above overfishing thresholds.

1. **Status in relation to Limits(s)**.
2. **Status in relation to Overfishing Limit**.
3. **Status in relations to Targets(s)**.

H STOCK AND FISHERY TRENDS

1. **Recent Trends in biomass or proxy**.
2. **Recent Trend in Fishing Intensity or proxy**.

Recent stock or fishery trends should be reported in terms of stock size and fishing intensity (or proxies for these), respectively. For full quantitative (Level 1) assessments, median results should be used when reporting biomass. Observed trends should be reported using descriptors such as increasing, decreasing, or fluctuating without trend. Where it is considered relevant and important to fisheries management, mention could be made of whether the indicator is moving towards or away from a target, limit, threshold, or long term average.

3. **Other Indices**. This section is primarily intended for reporting of trends where a Level 2 (partial quantitative) evaluation has been conducted, and appropriate abundance indices (such as standardised CPUE or survey biomass) are available.
4. **Trends in Other Relevant Indicators or Variables**. This section is primarily intended for reporting of trends where only a Level 3 (qualitative) evaluation has been conducted. Potentially useful indicators might include trends in mean size, size or age composition, or recruitment indices. Catch (effort) trends versus total allowable catch (effort) may be relevant here, provided these are qualified when other factors are known to have influenced the trends.

I PROJECTIONS AND PROGNOSIS

These sections should be used to report available information on likely future trends in biomass or fishing intensity or related variables under current (or a range of) catch levels over a period of years following the last year in the assessment.

1. **Time horizon for projection**. Last year of projection, e.g., 2022 (3 years).
2. **Future stock status**. Describe status over projection period using terms decrease, increase, fluctuate without trend.
3. **Probability of recommended (or current) catch causing biomass to remain below, or to decline below, limits**.
4. **Probability of recommended (or current) catch causing overfishing to continue or to commence**.

> **NOTE**: The New Zealand reporting format suggests that projected status at current catch levels or TAC levels should be provided as described below in italics. Other choices are possible, but something similar may be useful when full PA Policy frameworks are not completed to the extent that (for example) a harvest control rule is not applied.
>
> *When reporting probabilities of current catches or TAC levels causing declines below limits, the probability ratings in the PA Policy table provided above should be used. Results should be reported separately (i.e., split into two rows) if the catch and TAC differ appreciably, resulting in differing conclusions for each level of removals, with the level of each specified. The timeframe for the projections should be specified.*

Management Procedure (MP) updates in the context of an MSE process should be presented in a separate table. In years when an actual assessment is conducted for stocks under MPs, the MP update table should be preceded by a Status of the Stocks summary table.

J OTHER INFORMATION

1. **Qualifying Comments**. The purpose of this section is to provide any necessary explanations to avoid misinterpretation of information presented in the sections above. This section may also be used for brief further explanation considered important to understanding the status of the stock.

> **NOTE:** For the TESA workshop the Qualifying Comments field can be used for any information relevant to obligations under Fish Stock provisions and the PA Policy.

2. **Fishery Interactions**. This section should be used to list by-catch species and protected or endangered species interactions.

The draft template provided is a modification of the New Zealand format (Fisheries New Zealand 2018).

STOCK SUMMARY TEMPLATE

Version 1.1, 06-Sep-19

A	**Stock Description**	
1	Fish Stock Name	***<My fish stock>***
2	Stock Structure Assumptions/Basis	Little is known of the stock boundaries of cockles. Given the planktonic larval phase, many populations may receive spat fall from other nearby populations and may, in turn, provide spat for these other areas. In the absence of more detailed knowledge, each commercial fishery area is managed as a discrete population.
3	Assessment approach	Data-poor (indicators) Base case stock assessment Model ensemble Simulation (closed-loop or other) MSE (simulation with full resource user interaction) Other (specify)

B	**Reference Points**	
1	Limit Reference Points	$0.4B_{MSY}$

B	**Reference Points**	
2	Basis for Limit Reference Point (LRP)	Policy: provisional reference point International agreement Evidence of serious harm
3	Limit Fishing Rate (Removal Reference)	Overfishing threshold: F_{MSY}
4	Basis for Limit Fishing Rate	Avoid fishing mortality rates greater than F_{MSY} as per policy (DFO 2009)
5	Upper Stock Reference (USR)	$0.8B_{MSY}$
6	Basis for USR.	Policy: provisional reference point International agreement Not used as a reference point
7	Target Reference Point (TRP)	B_{MSY}
8	Basis for Target Reference Points	Policy (e.g., provisional PA reference point) International agreement Socio-economic considerations
9	Conservation objectives (biological)	*List here – is the objective measurable?*
10	Fishery objectives (socio-economic)	*List here – is the objective measurable?*
11	Evaluation (of management procedure performance against objectives, where a management procedure is defined as the data, assessment method, and harvest decision rule used to provide advice).	N/A Not conducted Retrospective (n years) Prospective (feedback simulation)

C	**Data**		
1	Main data inputs (*add rows as necessary*)	Description	Information Quality
		Research trawl survey biomass index (1998-2018)	1 – High Quality 2 – Medium or Mixed Quality 3 – Low Quality

C	Data		
		Proportions at age data from the commercial fisheries (2005-2017) and trawl surveys (1998-2018)	1 – High Quality
		Estimates of life history parameters	1 – High Quality
2	Data not used (*add rows as necessary*)	Commercial CPUE (does not track stock biomass)	3 – Low Quality

D	Assessment Methodology	
1	Assessment Type	1 – Full Quantitative Stock assessment 2 – Partial Quantitative Stock Assessment 3 – Qualitative Evaluation 4 – Low Information Evaluation
2	Assessment Method	Statistical catch-at-age model with Bayesian estimation of posterior distributions
3	Latest assessment date	2018
4	Next assessment date	2020
5	Basis for assessment frequency	Two-year TAC
6	Assessment Model(s) Presented	No Data-based Base case model only Base case and alternatives Ensemble of models Operating model reference set
7	Overall assessment quality rank	1 – High Quality 2 – Medium or Mixed Quality 3 – Low Quality
8	Changes to Model Structure and Assumptions	None since the 2012 assessment
9	Major sources of Uncertainty	The base case model deals with the lack of older fish in commercial catches and surveys by estimating natural mortality at

D	Assessment Methodology	
		age. This results in older fish suffering high natural mortality. However, there is no evidence to validate this outside the model estimates. Aside from natural mortality, other major sources of uncertainty include stock structure and migration patterns, and stock-recruit steepness.

E	Management Measures	
1	Harvest control rule	Yes/No – rationale for design
2	Control variable	Catch Effort Other
3	Spatial closures	Yes/No – rationale
4	Seasonal closures	Yes/No – rationale
5	Size limit	Yes/No – rationale
6	Gear restrictions	Yes/No – rationale
7	Other	

F	Historic Stock Trajectory	
1	<insert relevant graph>	<insert relevant graph>
2	<insert relevant graph>	<insert relevant graph>

G	Current Stock Status	
1	Status in relation to Limit(s)	B_{2018} has a low probability (< 10%) of being below the biomass limit.
3	Status in relation to overfishing	The fishing intensity in 2018 has a low probability (<15%) of being above the overfishing limit.
3	Status in relation to Target(s)	B_{2018} estimated to be $0.9B_{MSY}$; there is a high probability (75%) that spawning biomass is above target.

H	**Stock and Fishery Trends**	
1	Recent Trend in biomass or proxy	Biomass reached its lowest point in 2012 and has since consistently increased.
2	Recent Trend in Fishing Intensity or Proxy	Fishing intensity reached a peak of *F*=0.54 in 1999, subsequently declining to less than *F*=0.2 since 2006.
3	Other Indices	
4	Trends in Other Relevant Indicators or Variables	Recent recruitment (2005–2018) is estimated to be near the long-term average.

I	**Projections and Prognosis**	
1	Time horizon for projection	2024 (5 years)
2	Future stock status	Biomass is expected to fluctuate without trend over the next 5 years under recommended catch levels
3	Probability of recommended catch causing biomass to remain below or to decline below limits	Low likelihood (< 10%)
4	Probability of recommended catch causing overfishing to continue or to commence	Low likelihood (< 10%)

J	**Other Information**	
1	Qualifying Comments	The impact of the current young age structure of the population on spawning success is unknown.
2	Fishery Interactions	Main bycatch species are “list here”. Incidental interactions and associated mortalities are noted for “COSEWIC species”, “SARA species”, and “seabird species”.