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Proceedings of the Regional Peer Review on the Multi-Species Stock Assessment Framework for Great Slave Lake

Meeting dates: March 14–15, 2023
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Chairperson: Joclyn Paulic
Editor: Kayla Gagliardi

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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TABLE OF CONTENTS

SUMMARY

A Canadian Science Advisory Secretariat (CSAS) Regional Peer Review Process on a Multi Species Stock Assessment Framework for Great Slave Lake (GSL) was held March 14–15, 2023 as a hybrid in-person/virtual meeting. The fisheries of GSL are dominated by three species, Lake Whitefish (*Coregonus clupeaformis*), Lake Trout (*Salvelinus namaycush*) and Inconnu (*Stenodus leucichthys*). Expansion of the fisheries is expected in the near future and the development of an Integrated Fisheries Management Plan (IFMP) is critical for the long-term management of lake fisheries. Due to these initiatives and other existing pressures on the fishery, DFO Science has been asked to provide robust advice on the stock status for GSL fisheries to support the establishment of sustainable harvest levels and limit reference points for each of the three dominant species.

Due to challenges in the acquisition of data for GSL (e.g., funding, sufficient personnel, logistics) and data management, the quantitative approach to conducting a stock assessment is uncertain. Additionally, rapid development of alternative quantitative modeling techniques over the last ten years, especially in the area of data-limited assessment, could provide new opportunities. As a first step to the stock assessments, Science will explore the availability of monitoring data, and examine the feasibility of well-fit quantitative modeling approaches for each stock. The recommendations from this meeting will form the basis for the selection of candidate models that are well supported by the available information for each stock and ultimately generate a set of reference points for each of the three fish species.

The objectives of this peer-review meeting were to: 1) compile Lake Whitefish, Lake Trout and Inconnu harvest, abundance indicators, and biological/demographic parameters from GSL; 2) peer review compiled data and make decisions on datasets which are potentially able to support data requirements for full or data-limited quantitative assessments based on data quality; 3) explore the potential to apply various quantitative assessment models ranging from indicator-based assessments to full data rich stock assessment options; and, 4) select the appropriate models that will be used for the full stock assessment of each species and list assumptions and caveats with the use of the models.

This Proceedings report summarizes the relevant discussions and presents key conclusions reached during the meeting. The models chosen for each species were: Pella-Tomlinson to structure Bayesian-based Surplus Production Models (SPMs) by JABBA for Lake Whitefish, CMSY++ , Bayesian state-space implementation of the Schaefer surplus production model (BSM), Stock Synthesis (SS) for Inconnu, and CMSY++ , Bayesian state-space implementation of the Schaefer surplus production model (BSM) for Lake Trout.

Additional publications from this process will be posted on the DFO Canadian Science Advisory Secretariat website as they become available.

PRESENTATIONS

OPENING WELCOME/OVERVIEW OF THE CANADIAN SCIENCE ADVISORY SECRETARIAT (CSAS) PEER REVIEW PROCESS

Presenter: J. Paulic (Chair)

The Chair provided an overview of Canadian Science Advisory Secretariat (CSAS) and the peer review process as well as the role of participants, guidelines for the meeting, and the expected meeting products. The Terms of Reference (Appendix 1) were reviewed and the meeting agenda (Appendix 2) was presented. Participants from the meeting included affiliates from Fisheries and Oceans Canada (DFO) Science and Fisheries Management sectors (Ontario and Prairie Region and Arctic Region), Province of Manitoba, and University of Manitoba (Appendix 3).

CONTEXT FOR THE REQUEST

Presenter: J. Paulic (Chair)

Context for the request from the client sector was presented. The recommendations from this meeting will provide direction for quantitative analysis (i.e., models) for the upcoming (2023/24) stock assessments of Lake Whitefish (*Coregonus clupeaformis*), Lake Trout (*Salvelinus namaycush*) and Inconnu (*Stenodus leucichthys*). Three working papers (i.e., Research Documents; one for each species) were the focus of this CSAS review.

The commercial fishery revitalization strategy from the Government of Northwest Territories (GNWT) was noted and this could lead to increased pressure on the lake in upcoming years. Results from the upcoming stock assessments will be important for subsequent meetings in the next two years and will feed into upcoming management decisions and the ability to advance fisheries management on GSL.

WORKING PAPER OVERVIEW: BEST PRACTICE FOR DEVELOPMENT OF GREAT SLAVE LAKE WHITEFISH STOCK ASSESSMENT FRAMEWORK

Presenter: X. Zhu

Summary

The presentation encompassed factsheets, objectives, information to support the stock assessment framework, and recommendations. Lake Whtiefish is a cold-water coregonid, extensively distributed in all freshwater watersheds across the St. Lawrence River, Laurentian Great Lakes, Arctic Great Lakes, Mackenzie River basins and other inland aquatic ecosystems. In the typically oligotrophic GSL, Lake Whitefish dominated the abundance, biomass and production of fish communities over the history of the lake and fishery exploitation. Lake Whitefish has become the dominant species and has contributed a significant amount of fisheries production to sustain food security of Indigenous communities around the lake since their settlement. Since the mid-1950s, commercial exploitation of Lake Whitefish has expanded as a result of easy access to infrastructure and the gradual completion of a market network. The annual commercial harvest of Lake Whitefish alone was 5.74 million lbs in 1950. Between 1944 and2022, the annual average (mean ± SE) commercial harvest for Lake Whitefish was 2.41 ± 0.10 million lbs. Since 1990, the annual harvest for Lake Whitefish decreased to less than 20 thousand lbs in 2022. In addition to the dominance in GSL fish communities and highly profitable fisheries production, Lake Whitefish is a keystone species that stabilizes fisheries ecosystems through i) vital trophic connections with other prey-predator functional components, ii) a strong bottom-up forcing function behaviour maximizing nutrient catchments between river-lake interactions, and iii) a balancing component of the ecosystem,ensuring the biological integrity of the fish community and human well-being in terms of equitable wealth, food security, and sustainable socioeconomic development.

Since the commencement of GSL commercial fisheries, DFO has established a set of operational management regimes including setting up the fishing quotas, fisheries management areas (FMAs), and long-term monitoring and research programs. Along with the development of commercial fisheries and temporal variation in Lake Whitefish population dynamics, the fishing quota underwent a series of adjustments. DFO applied one fishing quota to the entire GSL commercial fisheries in 1944–1972, leading to an annual harvest for Lake Whitefish ranging from 227 tonnes in 1945 and 2,605 tonnes in 1950. Since 1973, seven FMAs have divided GSL and FMA-specific fishing quotas were introduced. Recorded variation of annual commercial harvest was between 90 tonnes in 2022 and 1,452 tonnes in 1991. All of these changes are recorded in annual data reports until 2002. In 2011, a DFO CSAS was held to integrate all sources of monitoring information and provide the assessment of the stock status of Lake Whitefish. In 2013, a DFO CSAS was held to evaluate the feasibility of the development of fishery-independent multispecies surveys including sampling protocol, age comparison, and gillnet catchability and fishing efficiency.

In terms of national and international guidelines, a GSL fisheries stock assessment framework for Lake Whitefish was proposed with explicit objectives to provide science advice for precautionary approach harvest strategies under the Fish Stock Provisions of the *Fisheries Act*. Available quantitative fisheries stock assessment models, underlying assumptions, and data requirements were used to create a decision tree(Appendix 4), considering three typical scenarios for the development of the GSL stock fisheries assessment framework. Scenario one is for the case when only harvest data is available and some demographic parameters of the exploited fish population. Depletion-based stock reduction analysis (DB-SRA; Dick and MacCall 2011) and Catch-MSY (CMSY; Martell and Froese 2013) toolboxes are available for some world-wide data-limited fisheries. Data-limited packages under Stock Synthesis (SS) and openMSE have recently been developed for the case of fisheries as well. Scenario two is for delay-difference model (DDM; Deriso 1980), SS (Methot and Wetzel 2013), and Just Another Bayesian Biomass Assessment (JABBA; Winker et al. 2018). These are valuable sets of surplus production models if there are longer time series of abundance index, catch per unit effort (CPUE), and harvest data available. Scenario three is termed as a full set of stock assessment models favoured by most fisheries assessment scientists. These sets of quantitative models require extensive data inputs including time series catch data, survey indices, age metrics, and biological information. These models are considered ideal by fisheries scientists to explore quantitative models such as a stock assessment program (ASAP; Legault and Restrepo 1998), SS, integrated statistical catch-at-age model (iSCAM; Martell et al. 2011), and Woods Hole assessment model (WHAM; Stock and Miller 2021). To test the balance between the feasibility of a specific model and the availability of data supports, the performance of JABBA by use of three surplus production model structures, Fox (1970), Schaefer (1954, 1957), and Pella-Tomlinson (1969) was demonstrated. Despite the indifference to deviance information criterion (DIC), evident difference could be seen in the outputs of stock status (B/B_{MSY} and F/F_{MSY}) and reference points (MSY – maximum sustainable yield, LRP – limit reference point, USR – upper stock reference) by respective surplus production model structures. All reference points of three surplus production models consistently indicated that GSL Lake Whitefish is in a healthy state. Meanwhile, a catch-only model, Catch-MSY, was run and the model outputs showed that the stock status of Lake Whitefish is in the cross-boundary of critical and cautious state. Thus, model selection is key to conducting GSL fisheries stock assessments.

Associated with the model performance, underlying assumptions, and possible data support, three strategies for conducting quantitative fisheries stock assessment for Lake Whitefish in GSL were recommended: 1) JABBA should be used to generate a set of lake-wide LRPs because there are 25 years of CPUE and a full time-period of commercial harvest; 2) Catch-MSY and JABBA should be used for Lake Whitefish in FMAs II, III, IV, and V where the time series of CPUE were less than 20 years; and, 3) SS and JABBA should be used for Lake Whitefish in the Western Basin (IW and IE) because there are full sets of monitoring datasets (CPUE, age and growth, age composition, maturation and fecundity, selectivity, and harvest).

Discussion

For the 'age distribution and multiple comparison of age difference between fisheries management areas' figures in the working paper, it was recommended to present the percentage frequency for the y-axis, derived from the actual frequency. The total sample size should be used to avoid potentially inflating the bars.

For Catch-Per-Unit Effort (CPUE) it was noted that new fishery-dependent (FD) studies data from 1973–1989 for Lake Whitefish was recently found in March 2023. There is also some newly found data for Lake Trout which will be shared with the working paper authors. Additionally, there was a discussion about standardizing CPUE data across different FD surveys and fishery-independent surveys to obtain a more comprehensive understanding of the fish population. However, participants raised concerns about hyperstability and the need for more detailed information on the fishery to calculate hyperstability accurately. It was emphasized that the available data for Lake Whitefish is not equivalent across sources, and assumptions about uncertainty must be carefully considered to avoid drawing dangerous conclusions. Nevertheless, the consensus was to use all available information that contributes to CPUE in any form, as it would provide valuable insights rather than leaving gaps in the analysis. Model programs, such as an age-structured model (ASM), could calibrate the data and compare outputs with and without the newly acquired information, offering a ballpark estimate. However, it was flagged as important to include cautionary text when incorporating these additional elements into the model. For FD CPUE data, it could be helpful to look at the model with and without it to see how results influence each other or if it is inflated. The recommendation was to calculate CPUE with, and without FD CPUE data, to see the sensitivity, and assess/calibrate the degree of bias, and also check if there are any years of overlap. It would also be helpful to anchor the timeline with earlier data.

Regarding commercial harvest for Lake Whitefish, it was recommended to designate the fish plant closure as the endpoint for the time series in the working paper figure and consider it as a reference point. Participants highlighted the difficulty of including periods with no harvest data in the model for some management areas, as the model would misinterpret it as a stock collapse and assume the effort stays the same in the area. It was noted that some fishers in the affected areas still sell their catch locally instead of at the plant, which poses challenges for data collection. While mandatory reporting measures are in place to estimate catch, local sales and fisher culls are not always reflected in the reported data. The logbook data may play an important role in identifying associated gaps. While it is currently not part of the assessment, there might be an opportunity to include this data in the final assessment once it becomes available. At least a few years of data should be available to distribute to the authors of the working paper.

It was recommended to enhance figures in the working paper where appropriate, such as the one for CPUE by adding variance information. Including variance information, particularly for the combined values, would provide a clearer understanding of the overall variability and improve the interpretation of the data.

A decision tree for the stock assessment framework (Appendix 4) was presented and it was unanimously agreed upon as a useful reference for all three species in this assessment (Lake Whitefish, Inconnu, and Lake Trout). This figure was considered a valuable tool in guiding the assessment process and ensuring consistency.

Three production function forms; Fox, Schaefer, and Pella-Tomlinson, were used to structure Bayesian-based Surplus Production Models (SPMs) by JABBA. For the SPMs it was recommended to include uncertainty values in the summary table of the working paper to facilitate comparisons across different model types. While the Maximum Sustainable Yield (MSY) can be useful as a signpost, caution should be exercised when interpreting it as a quota. It was noted that the confidence intervals are currently centered around fishing mortality, and optimal fishing mortality values should aim to be 80–90% below the MSY level. The use of lower confidence levels for MSY in the case of Arctic Char (*Salvelinus alpinus*) was mentioned, as it always resulted in lower values; however, applying a similar approach to other species would require further discussions and rule adjustments.

It was agreed upon that the Pella-Tomlinson-1 (PT-1) model was preferred over the Shafer model due to its higher resilience and incorporation of fecundity estimates, corresponding to 40/80% of the biomass at Maximum Sustainable Yield (BMSY). The relationship between Lake Whitefish and Lake Trout was highlighted and it was questioned whether Lake Whitefish could potentially suppress Lake Trout after a collapse. Evidence was cited from the Lake Erie area, where a high presence of Lake Whitefish coincided with low Lake Trout numbers. It was suggested that when Lake Whitefish numbers decreased, Lake Trout populations increased, as both species share the same habitat but occupy different trophic levels. There is also some information to suggest that Lake Trout may feed on benthos when young, potentially creating a scenario where the suppression of Lake Trout could lead to increased feeding opportunities for Lake Whitefish which could be a possible explanation for why higher Lake Trout catch will depress the catch of Lake Whitefish. Differences in results and the need for increased priors for Lake Trout's intrinsic growth rate (r) were mentioned as areas for future investigation. The importance of considering the CPUE data as an index of relative abundance and its influence on the relationship between the two species was emphasized. It was noted that more evidence is needed to support the assumed time-varying r and K in SPM, in particular, critical information on recruitment and maturation. The current data cannot produce or replace information on the recruit or spawner index.

Participants discussed the potential bias of the FD data and explored ways to assess its magnitude. It was noted that other sets of FD data dating back to 1985 were available, and the suggestion was made to find a way to incorporate this data into the model. It was suggested to try to calibrate the CPUEs in overlapping periods with FIS and FDS; however, this is challenging since there were no CPUEs from both efforts at the same time and area.

It was reiterated that the goal of this process for all three working papers was to determine which models are acceptable and to provide specific recommendations for model formulations. These recommendations would be included in the conclusions of the working papers, serving as a reference for the upcoming stock assessment. The authors agreed that while additional analysis might be needed, it would not be feasible to incorporate entirely new models between this meeting and the upcoming stock assessment meeting. However, small changes and adjustments could be considered. It was emphasized that the research documents from the framework meeting must be referable for the upcoming stock assessment meeting, ensuring transparency to outside reviewers.

Exploring local individual freshwater market data was suggested as a means to expand the FD database for CPUE. If this data is available, it could offer innovative insights by considering factors such as, the number of fishing days and potentially the fishing power of vessels. Incorporating this data would also enhance the understanding of effort dynamics and improve the analysis of CPUE. For the Kobe plots, it was recommended to rerun them with the truncated time series, as they should provide a representative depiction of the later years. Participants expressed curiosity about the significant differences observed and suggested including an index for abundance or biomass to understand the underlying reasons better.

It was recommended to include equations in the subsistence harvest section of the working paper to clarify the calculations performed. Furthermore, participants emphasized the importance of clearly indicating the data sources in general, particularly for local markets and logbook data, to enhance transparency and reproducibility of the assessment. It was concluded that the preferred approach for Lake Whitefish is the PT-1 model since it is based on biological thinking and presents less variation than the other models.

WORKING PAPER OVERVIEW: GREAT SLAVE LAKE INCONNU STOCKS TRENDS AND ASSESSMENT MODELLING

Presenters: Y. Janjua and D. Enright

Summary

Inconnu (*Stenodus leucichthys*) in the Northwest Territories is found throughout the Mackenzie River basin, including Great Slave Lake (GSL) and several major tributaries. A historical review of Inconnu's presence throughout GSL strongly suggested that this species is vulnerable to recruitment overfishing. With decades of overfishing, several Inconnu populations in GSL are extirpated. A recent study assessed the population genetics of Inconnu sub-structuring among locations in GSL corresponding to three major river systems: Slave River, Buffalo River, and Marian River, suggesting that each river supports a genetically distinct Inconnu population. Mixed stock genetic analyses were conducted on commercial fishery samples collected from different management areas suggesting that Buffalo River Inconnu stock contributes around 17% and 19% to the commercial catch of Inconnu in Areas IW and IE, respectively, and around 10% in Areas III and Area IV. Slave River stock contributes 66% and 75% of Inconnu commercial catch in Areas IW and IE, respectively. Areas II and III are composed mostly of Slave River stock. Marian River stock contributes around 75% of the Inconnu catches in Area IV.

A gillnet sampling program at the mouth of the Buffalo River in the spring (May–June) was started in 1947 and conducted in varying years between 1947 and 2011. Since 2013, this monitoring has been done annually and reported CPUE ranged from 11 mature females/50m/h in 1977 to 0.3 mature females/50m/h in 2021. At the Buffalo River mouth, the instantaneous annual mortality rate was very high for some years, e.g., 1979, 1985–1987, where survival rates were less than 50%. The mean fork length decreased from 1940 to 1950 at the Buffalo River mouth. Because of high harvest rates in the late 1970s, mean fork length decreased further in the 1980s. In the 1990s, there was an increasing trend in mean length that started decreasing again in 2015. There was a decreasing trend in mean age at catch from the start of the commercial fishery, and it decreased from 10 years to a mean of 9 years in the 1950s, 8 years in the 1970s and 7 years in the 1980s and 1990. Since 2010, there has been an increasing trend in mean age at catch. In the Slave River, there was a decreasing trend in mean fork length from 2018 (796 mm) to 2022 (747 mm). The same trend was observed for the mean weight. In Buffalo River, there was an increase in length and age at 50% maturity in the 2010s compared to previous decades.

CMSY++ was used for stock assessment modelling and estimates of fisheries reference points (MSY, FMSY, BMSY) as well as status or relative stock size (B/BMSY) and fishing pressure or exploitation (F/FMSY). Bayesian state-space implementation of the Schaefer surplus production model (BSM) was also used with the inclusion of relative abundance data. Retrospective analyses were conducted to evaluate model performance. Stock Synthesis (SS), a fisheries model that is an implementation of integrated analysis, was also used to assess the Buffalo River stock. This model also used demographic time series data. The models tested (CMSY++, BSM, and SS) proved to be effective analytical tools for determining sustainable harvest levels with the available data for Inconnu. The models could converge and provide various stock metrics such as Biomass, F, and Spawning Stock Biomass. For the key stock, Buffalo River, the models showed similar patterns consistent with what is known from other indices. As relative abundance data (CPUE) and more extended time series for demographic trends are available from Buffalo River mouth, monitoring only, SS and BSM may not be run properly for the other GSL Inconnu stocks and combined Inconnu stocks. However, using harvest data for the whole main basin and distributing MSY to various stocks on a mixed stock genetic analysis basis provided reasonable results. External reviewers considered all models to be effective and useful and should be used in the coming stock status analysis.

Discussion

Participants highlighted the availability of age structure information for Buffalo River at the start of the fishery before it crashed and also for the Slave River. Including the back-calculated data and age structure figures (from start of fishery) from Howland (2005) was recommended in the working paper. Additionally, the software used for fitting the data, specifically the Fishery Analysis and Modelling Simulator (FAMS; Slipke and Maceina 2014), was identified as a potential problem.

Concerning the mean fork length of Inconnu, the possibility of cohort effects in the 1980s was discussed, and it was suggested that the uncertainty of these effects be addressed in the working paper. Frequency and cohorts captured in past assessments were also noted as relevant factors to consider.

For the Catch-MSY (CMSY) model and Schaefer surplus production model (BSM), there was a discussion regarding the estimation of carrying capacity (K), intrinsic growth rate (r) and catchability. It was acknowledged that fitting these parameters was challenging. A question was raised about potential changes in K from the beginning of the time series to the end. It was clarified that K is kept as fixed, and that this is a reasonable assumption as there were no significant changes in the lake or spawning areas to indicate that it should be changed.

The next point of discussion was whether to re-fit the model without the two high harvest years in the dataset. The idea of cohort effects influencing high catches was raised, indicating that high catch numbers could be attributed to strong cohorts rather than high CPUE. However, it was noted that the residuals appeared to show cyclical patterns, which could be attributed to factors such as the availability of cisco populations as a food source for Inconnu or price cycles affecting fishing efforts. A participant additionally noted that local people have commented on the variability and cyclical patterns of cisco populations in Great Bear Lake. It was also noted that Inconnu had high fecundity, meaning that a large standing stock might not be necessary for successful recruitment. The lack of data available per year was acknowledged, making it difficult to make definitive decisions based on the existing dataset. It was suggested that using CPUE from the analytical graph for BSM analysis of Buffalo River Inconnu, showing the fit of predicted to observed CPUE, could be a viable alternative. Regarding this analytical graph for BSM, the question arose about how to match suggestions between different areas. The suggestion was made to use mixed stock fishery analysis tables, which would require genetic data to be separately reviewed before the stock assessment process. The potential inclusion of mixed stock fishery analysis in the strategy was discussed, particularly with the MSY target of 8 tonnes for Buffalo River. It was noted that the current catch from Buffalo River, based on mixed stock proportions, ranged from 5 to 10 tonnes. The proportion of stocks and their potential changes over time were also considered, and it was noted that this information should be available every second year.

The influence of priors on the model outcomes was questioned, as they seemed to have a restrictive effect. It was acknowledged that the best available information was used in a data-poor situation like this. However, it was emphasized that the data, apart from harvest, did not provide much informative value.

It was asked why the depletion model was set to medium over the whole lake, and clarified that two scenarios were used: GSL medium and strong depletion for CMSY. These scenarios were based on data from 1972 to 2021 and compared. These simulations were not included in the draft working paper, but adding them was recommended so they can be available for the stock assessment meeting. Considering sensitivity analyses of r and final depletion (B/K) were emphasized. It was acknowledged that the start of B/K did not include the extirpated stocks, and it was recommended to keep the overall medium depletion for the whole lake while using a strong depletion scenario specifically for Buffalo River. It was recommended to set up a scenario that combined parameters for both depletion and resilience. Additionally, it was mentioned that the literature suggested a slightly higher r for Inconnu, and it was proposed to conduct a sensitivity analysis with different r levels and depletion scenarios. However, it was noted that if this analysis is done it would only be part of the upcoming stock assessment research document, as further discussion was needed before including it in the current working paper.

The importance of considering all stocks' depletion and including extirpated stocks in the analysis was emphasized. There was a suggestion to include a full history of strong depletion for the whole lake, including the extirpated stocks from 1972 onwards, while presenting medium depletion for practical management purposes and severe depletion for Buffalo River. Different perspectives were expressed regarding the management approach, with one participant suggesting to focus on the period from 1972 onwards due to mixed stock analysis and the presence of six stocks at that time. However, others disagreed and emphasized the importance of presenting all three scenarios: the period from 1945 to the present for conservation purposes, the period from 1972 to the present for practical management, and severe depletion specifically for Buffalo River. The consensus was that while all scenarios present unfavorable situations, providing a comprehensive overview of the species' status is still important since it has not done well in GSL.

With regard to the Stock Synthesis (SS) model, the discussion revolved around the standard deviations, with some participants expressing concern over their small size and how they seemed unrealistic. It was noted that this may have been due to the amount of confidence or the potential impact of female-only life history parameters on biomass estimates. It was asked if there could be sex bias occurring when fishing and noted that the table presenting Buffalo River Inconnu maturity indices showed a relatively equal distribution of sexes. There were speculations that commercial fishermen might be targeting Inconnu during spawning. However, the presenter expressed doubt about this assumption, stating that Inconnu do not aggregate before moving to rivers. Regarding the differences between males and females, it was highlighted that females had higher size-at-age and were generally larger than males, making them vulnerable to commercial gear before reaching maturity. The implications of this sexual dimorphism were not fully understood, but it was suggested that male-specific life history parameters should be added back into the model. The growth rates and selectivity were found to be different between the sexes, emphasizing the need to include size difference information in the working paper. As females drive productivity, the increased risk of harvest for females could be serious. The discussion concluded with a recommendation to either estimate male life history parameters separately or keep them fixed but separate from females, as different parameters would be needed for each sex.

A participant recommended standardizing the maturity estimates based on otoliths, since if spawning biomass is changing over time a signal should be seen with recruitment. It was confirmed that the data had been converted, and the final version used otolith data instead of scales. This would be important information from the catch-at-age model and combining age structure into the model.

It was indicated that for the SS modelling there might be issues with the model's performance, potentially related to the tightness of priors. It was recommended to check the effects of this, as it could explain the tight confidence interval. The importance of multi-model comparisons to address uncertainty was emphasized. It was recommended to include points about how the different models are showing similar results in the conclusions of the working paper with the disclaimer that this is not final advice, but rather preliminary illustrations/comparisons between each. This would apply to the working papers for all three species. It was reminded that the objective of this meeting was to focus on only providing recommendations to inform current and future models at this stage.

With regard to the SS time series plots, the topic of density dependence in the model was raised. It was suggested that the high fecundity of the species might lead to reproductive success even with a small number of females, given the right conditions. The shape of the recruitment pattern was found to be consistent with the spawning stock biomass (SSB) from the 1980s onwards, but not in the 1970s, indicating a potential density-dependent effect. It was recommended to investigate how the SS model deals with density-dependent spawning recruitment.

The consideration of climate variables in the model was also discussed. It was noted that climate change would not be incorporated into the model at this stage but would be part of the discussion on the results during the upcoming stock assessment meeting. The possibility of incorporating an environmental sub-model into the SS framework was mentioned, although it is uncertain how to do so at the moment. It was acknowledged that the correlation between climate variables and the species demographic trends could be positive or negative, but it was known that Inconnu is more northerly distributed and requires cold water, while Lake Whitefish and Lake Trout have different distribution patterns. It was noted that this region could explore more quantitative approaches, particularly regarding Lake Whitefish and Lake Trout, as they are widely distributed, and perhaps more resources should be put towards this.

During the discussion on the choice of preferred model for Inconnu, it was agreed that presenting multiple model options at this stage would be most appropriate. It was reminded that the objective of this meeting was not to necessarily determine the best model but to present the outputs from different ones and see if they converge. A participant emphasized the need to present the pros and cons of each model to help DFO Fisheries Management (FM) make informed decisions considering the compounded variability of multiple models.

The implementation of the Precautionary Approach (PA) was seen as a way to address uncertainties, and having three models could provide more confidence in the results. The opportunity to have technical discussions at this stage to avoid complications during the stock assessment meeting was highlighted. A participant mentioned how they attended workshops on data weighting and model comparison where the need for a common language to communicate fishery status results was emphasized. The possibility of combining mathematical models was discussed, although the selection of parameters and the choice of model would depend on management objectives.

The discussion concluded that the CMSY and SS scenarios should be presented, along with the parameters for comparison. The table that summarizes the scenarios would be a product to bring to the stock assessment, rather than including every output in the working paper. Weighting models using multi-model compression was deemed useful if possible. It was noted that it would be beneficial to explore JABBA, as used in the Lake Whitefish assessment, for Inconnu and Lake Trout. However, since it had not been run yet, further discussions were needed to determine the next steps and whether to include it in the stock assessment working papers.

Considering this was a framework meeting, it was suggested that one of the outputs should be a plan for conducting comparison and ranking among the models. It would be beneficial to come up with a way to present the reasons for selecting a model amongst the many presented as part of the framework to avoid having to go through each scenario at the stock assessment meeting.

Lastly, a participant asked whether Inconnu should be considered for listing under the federal *Species at Risk Act* (SARA) or under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) since extirpation has occurred in some areas. This is currently under discussion with COSEWIC, although it was noted that some of the extirpations were likely not caused by overfishing, rather other anthropogentic impacts, such as the construction and presence of a dam. The participants acknowledged that rehabilitating the species would be a good objective and this was noted as an action item for FM to follow-up on.

WORKING PAPER OVERVIEW: LAKE TROUT STOCKS TRENDS AND ASSESSMENT MODELLING

Presenters: K. Howland, H. Chymy and Y. Janjua

Summary

Lake Trout are a prominent species in Great Slave Lake (GSL), Northwest Territories. Variable monitoring has occurred for harvested populations of GSL Lake Trout, an important component of the largest northern commercial freshwater fishery, and a valued species for both recreational and subsistence fisheries of the area, with multiple phenotypes and genotypes being present in the lake. Commercial fishing on GSL began in 1945 but between the years of 1944–1947, the lake was also under biological investigation. From an initial research investigation into species composition (1944–1945), Lake Trout accounted for 10% of the fish community by numbers and 46% by weight. The evaluation of commercially sampled Lake Trout from 1945–1964 reveals a general decline in average weight and availability (a measure of CPUE) in all lake areas, likely due to heavy commercial gillnetting. The first twenty years of commercial fishing on GSL saw a rapid increase in the exploitation of the long-accumulated fish stocks. Lake Trout commercial harvest peaked in 1949, followed by a sharp decline leading management to close the far East Arm to commercial fishing in 1974 to protect the species and the lucrative sport fishery of the area. Misinterpretations from initial research investigations on the production capabilities of GSL likely contributed to the crash of Lake Trout in the 1970s in the Main Basin.

Presently, multiple ongoing GSL surveys sample Lake Trout. These include a multi-mesh gillnet multispecies monitoring program initiated to monitor relative abundance/biomass in different management areas and collect biological data for each species which began in 2011, however, only Management Areas IW and IE are monitored annually. Results of these, and other surveys, have demonstrated interannual fluctuations in Lake Trout average, maximum, and minimum age, length, and weight, with no visible trends in mean age, size, or weight in the Main Basin and East Arm, both in multi-mesh and commercial gillnet monitoring. No significant difference of Biomass per unit effort (BPUE) was detected by depth strata in Areas IE, IW, II and significantly greater BPUE was found in bottom set nets in Areas III, IV and V. Relative biomass (BPUE) was comparatively high in Areas with less fishing pressure (III, IV and V). In the west basin (Area IW+IE), where the majority of commercial fisheries are taking place, there was a sharp decrease in Lake Trout biomass in 2018 after high commercial catch in 2017–2018, however in 2022 it showed indications of a return to the 2017 level. Lake Trout are considered to have a regular contribution to the surveyed fish community in the upper (IRI 3%), and middle (4%) of the water column, and to be rare (0.67%) in bottom waters; across all three sampled depths strata. Lake Trout results for recent year's survey data estimate natural mortality in the Main Basin at 17% and 12% in the East Arm, species composition of Lake Trout at only 0.6% of the fish community by numbers, and 6.6% by weight based on catch data, only a small fraction of values reported in the initial years of the fishery.

In GSL Lake Trout stocks, identification of stock reference points is complicated by lack of data. Without appropriate, age-structured time series data, it is difficult to use age-structured data-rich stock assessment models. For GSL Lake Trout, longer time series data are only available for catches in different management areas. Therefore, data-poor catch-based models are justified for this stock assessment. Along with harvest data, fisheries independent CPUE data is available only for recent years. CMSY++ software allows for the incorporation of available CPUE data to produce a second set of reference point estimates through Bayesian Schaefer model (BSM) modelling, and was therefore used in this assessment. This approach was supported based on the fitting of BSM models to recent CPUE time series data, especially for Areas IW and IE, where there has been extensive fishing pressure in recent decades. With catch-based models, it is difficult to assess other management areas (e.g., Area II, III and V) having low commercial fishing in recent years. However, these areas may be assessed by using a shorter time series. Modelling GSL Lake Trout with CMSY++ as a single stock, using a historical harvest time series will be uncertain because Lake Trout commercial fishing has been confined to the western basin only for the last few decades, thus area-specific models are a preferred approach. Estimates of current Lake Trout relative stock size (B/BMSY), and maximum sustainable yield (MSY), in addition to FMSY (fishing pressure required at MSY), and fishing pressure in 2022, were identified at the whole lake level and by management areas for this fishery through the application of CMSY and BSM. Both models were proven to be effective analytical tools for determining sustainable harvest levels and stock status with the available data. External reviewers considered modelling results to be effective and useful in future stock status analysis and recommending limit reference points for the management of Lake Trout in GSL.

Discussion

The working paper authors noted that throughout commercial harvest history for GSL (for all areas combined), there had been a reduction in mesh sizes used in fishing gear. However, larger mesh (6”) has occasionally been used to target Lake Trout. The potential impact of mesh size on catchability was noted, and how FD data could be used to explore the average availability of Lake Trout and its potential correlation with earlier data.

It was asked and confirmed that of the morphs of Lake Trout, leans are speculated to be more commonly found in shallow areas, while siscowets (fats) are more prevalent in deeper waters. This led to inquiries about the known spawning areas of Lake Trout. While there was some information available regarding the fall spawner index and movements of Lake Trout to specific areas during spawning, there was also an acknowledgment that more research, including genetic sampling and tagging, is necessary to gain a better understanding of movement patterns. The participants discussed the possibility of Lake Trout moving between their home ranges and spawning grounds. Although there are uncertainties, it is possible that they primarily move from deeper to shallower areas, congregating at reefs for spawning purposes. During the discussions, it was noted that genetic samples collected directly from the spawning area indicated some movement of Lake Trout from other areas. The current DFO tagging (acoustic telemetry) study may be able to provide further insights into Lake Trout movement patterns. The possibility of siscowets engaging in vertical migration was discussed, and it was speculated that this is done based on their feeding habits (i.e., work conducted by Zimmerman et al. 2009). It was questioned whether the modeling framework should focus solely on the West Basin, considering the observed separation between the East and West Basin, as Lake Trout were not found to be moving extensively across the lake. It was noted that a few individuals do move, but it was not considered a dominant pattern and there is more discussion around the inclusion of Area 6 in the modelling presented later on in the working paper. It was noted that if movement findings can be linked to the age of Lake Trout, this could be beneficial to include in a future paper.

The number of ecotypes observed in the main basin of the lake was also a topic of discussion. Participants noted that there are fewer identified ecotypes in the study area compared to Great Bear Lake, and it was explained that limited focus and smaller sample sizes in GSL may be the cause. Sampling efforts were concentrated in a small area of the East Arm, which may have resulted in a narrower representation of ecotype variety in the past.

The Depletion-Based Stock Reduction Analysis (DB-SRA) model was presented next and it was decided not to proceed with it due to limited data and contrasting information from different time periods. A participant raised the possibility of including 1970s data in the candidate models to enhance the analysis of CPUE for Lake Trout. However, it was pointed out that the CPUE data, collected through the Creel survey, was only available for Area 6, raising concerns about its representativeness for the entire study area. Additionally, the use of commercial catch trends as a proxy for CPUE or relative abundance was discussed. It was acknowledged that this approach could be confounded by changes in stock size and other factors, and therefore, caution was advised in interpreting such data. It was noted how it appears that Lake Trout catches are decreasing, however, catches do not relate to stock size, and it is easier to catch Lake Trout if Lake Whitefish are stable.

It was noted that the estimate for modeling implies that Lake Whitefish stock size has been relatively stable since after 1973. Therefore, there may be a case to be made about how Lake Trout are being disproportionally caught more whether they are being targeted more or not. It was flagged that fishery dynamics should be considered in this case since less experienced fishers may have higher success rates with catching Lake Trout as they are generally easier to find and closer to shore in fall compared to more experienced professionals primarily targeting Lake Whitefish. The suggestion was made to consider incorporating this information as a proxy for CPUE in the modeling framework to account for the differing skill levels of fishers. This idea was proposed, but no unanimous agreement was reached. The presenter expressed discomfort with this approach, citing the potential uncertainty caused by other events, such as by flooding in Hay River, which could introduce various factors affecting species abundance in commercial fishing. As a result, it was decided not to pursue this option.

On the topic of catch time-series and B/K inputs, it was recommended to add more information to the working paper for the '0.01–0.4–start' area-wise choice of B/K section since low catches during that period may have been influenced by factors such as reduced fishing effort or reporting, which could affect their comparability to other data points. Furthermore, if such information is available, it should be acknowledged that uncertainties exist regarding the low catches, including factors like the number of fishermen and fishing plants involved.

Regarding CPUE analysis, it was suggested that the sample sizes of the data should be looked at and excluded if they are too low. Additionally, it was noted that in order to make CPUE comparable to other species, factors such as the size of the fish, the number of nets used per year, and the specific locations where the nets were set should be considered. A participant will provide relevant data for these analyses. The use of multi-mesh nets was questioned due to the lack of size selection for Lake Trout, and it was asked if it would be possible to remove small mesh sizes. It was noted that the multi-mesh nets consist of two small sizes, and while smaller fish will swim through larger mesh sizes, larger (and smaller) size classes of trout can still be caught in smaller mesh sizes. It was suggested to verify this by cross-referencing with commercial gill net data and exploring that dataset further.

Participants discussed the possibility of conducting a retrospective analysis, aiming to assess the influence of the last year's data on the models and ensure that they are not skewed by unusual data points, which could be the case for Lake Trout especially. It was noted as a future consideration for FM that since there was a lot of emphasis on spatial differences due to management areas specifically, it would be useful to know if there could be an opportunity to explore if these management zones are truly relevant or if there are more biologically significant regions that should be considered. Shifting management zones based on geographic data was considered a possibility.

It was acknowledged that factors beyond biology influence the current management areas, but utilizing acoustic telemetry and genetic data might offer a better understanding of fish movement and help refine the delineation of management areas. The discussion also highlighted a similarity to the Inconnu scenario, where high harvest in historical years had impacted the model results. It was agreed that using the truncated time series for analysis would be more appropriate. The stock assessment working paper should outline the reasons for excluding certain data points and provide information on the locations covered and the number of fish tagged, recovered, and examined to support this decision.

Participants raised the question of utilizing data from a tagging study conducted in the 1940s to estimate the initial abundance. It was proposed to incorporate this historical data into a simple model to calculate the initial abundance. It was acknowledged that this approach is not necessarily relevant to management; however, it could still provide a potential target or reference point. It was noted that the majority of the tagged fish were likely Lake Trout and Lake Whitefish, allowing for a relative estimation of their total numbers. This information could be compared to the quotas set for these species and the authors agreed to further investigate this approach.

The idea of using age data from the inception of the fishery to calculate the natural mortality rate without considering fishing mortality was proposed. It was suggested to utilize the older data to obtain the necessary numbers for establishing a starting point. However, determining the number of fish that were handled but not tagged would be challenging. It is assumed that the population is closed geographically but this is not always the case. Although female tagging had already commenced, it was uncertain if the tagging locations were documented. It was suggested that estimating abundance based on a single location might be more appropriate. By assuming a closed population of spawning fish that consistently return to a specific area, it may be possible to obtain an abundance estimate for that particular region. However, it was noted that the recovery of tagged fish poses a challenge in terms of achieving reliable recovery samples. If only a few tags are returned, it could result in an overestimation of a very large population, as the tagged fish may have moved away, making it difficult to determine the proper recovery rate. It was emphasized that the goal is to try and establish a reference point using the available data, recognizing that it does not need to be perfect. Using the existing information to provide a starting point for the model was recommended, although it will require making certain assumptions.

GENERAL CONCLUSIONS

Throughout the meeting there was a comprehensive discussion about the implications of conducting a multi-species stock assessment and how to translate the individual stock advice into mixed stock quotas. It was questioned whether to separate the quotas for each species or to continue with the combined quota approach. Participants suggested that the fishery should move away from combined quotas and modeling should be looked at separately for each species to facilitate independent quota setting and this recommendation could be made at the upcoming stock assessment meeting. It was noted that if combined quotas are to be used, then the framework will need to be flexible enough to accommodate this. It was flagged that it has been inherent throughout this process to move towards independent quotas, but there are factors to consider, such as how this is a competitive fishery without selective fishing. It may also be possible to consider spatial patterns of the three species for management. Although Lake Trout and Lake Whitefish are already considered as separate stocks, there are challenges, since it is difficult to fish selectively for them when they are in the same area.

A participant questioned the number of independent signals in the series (correlation among areas), which applied to all three working papers. It was noted that this issue is more for future and long-term considerations and is particularly relevant for Lake Whitefish, where more data is available. It may be possible to explore this further once logbook data is available.

Concerning the inclusion of the ecological approach and history, there was a suggestion to address this during the upcoming stock assessment CSAS meeting instead of the framework, possibly in the context of climate change. There was consensus to acknowledge the importance of this aspect in the working papers and potentially explore it further in the future, for example with SS models. This will be noted as a piece to discuss with the steering committee before the stock assessment meeting.

It was recommended to add a section to the working papers that acknowledges that the models are acceptable for assessment and to include recommendations for further exploration and adjustments. The meeting participants agreed that the models reviewed were adequately presented, but it was emphasized to perform sensitivity analyses due to the models' sensitivity to input parameters. Area closures could also be influential factors. The potential exploration of a model that considers environmental variables (i.e., limnology data) was discussed, but no specific model was defined. Some stock assessment models for salmon involve oceanographic information, but such models require extensive historical data.

Regarding data reporting, the idea of combining data for the three species in a separate report was favoured by some participants, but it was agreed that the focus of the current meeting was on assessment models. However, it was suggested to consider incorporating background information in the working papers or create a separate background report supporting the stock assessment.

The group agreed to accept the three working papers as research documents with the addition of the verbal and written comments provided before and during the meeting. It was suggested to consider publishing additional pieces, such as technical reports that could be used as references in upcoming working papers.

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APPENDIX 1. TERMS OF REFERENCE

Stock Assessment Framework for Lake Whitefish (*Coregonus clupeaformis*), Lake Trout (*Salvelinus namaycush*) and Inconnu (*Stenodus leucichthys*) in Great Slave Lake, Northwest Territories

Regional Peer Review – Ontario and Prairie Region and Arctic Region

March 14-15, 2023
Winnipeg, MB
Virtual Option Available

Chair: Joclyn Paulic

Context

The fisheries of Great Slave Lake (GSL) are dominated by three species, Lake Whitefish (*Coregonus clupeaformis*), Lake Trout (*Salvelinus namaycush*) and Inconnu (*Stenodus leucichthys*). Expansion of the fisheries is expected in the near future and the development of an Integrated Fisheries Management Plan (IFMP) is critical for the long-term management of lake fisheries. There are ongoing pressures on DFO Science to provide robust advice on the stock status for Great Slave Lake fisheries to support the establishment of sustainable harvest levels and limit reference points for each of the three dominant species. A previous assessment of Lake Whitefish for GSL was not definitive due to missing data at the time of the assessment (DFO 2015). Multiple stocks of Inconnu exist within GSL, however only one stock, the Buffalo River, was assessed within a precautionary approach framework (PA) with limit reference points established (DFO 2013). Lake Trout has not been assessed in recent decades.

Due to challenges in the acquisition of data (e.g., funding, sufficient personnel, logistics) and data management, the quantitative approach to conducting a stock assessment is uncertain. Additionally, there has been a rapid development of alternative quantitative modeling techniques over the last ten years, especially in the area of data limited assessment that could provide new opportunities. As a first step to the stock assessments, Science will explore the available data and modeling approaches for each stock with the aim of using the highest level possible in quantitative analysis. The recommendations from this meeting will provide direction for quantitative analysis (i.e., models) for the upcoming (2023/24) stock assessments of these species.

Objectives

The objectives of this peer-review meeting are to:

1. Compile Lake Whitefish, Lake Trout and Inconnu harvest, abundance indicators, and biological/demographic parameters from Great Slave Lake.
2. Peer review compiled data and make decisions on datasets which are potentially able to support data requirements for full or data-limited quantitative assessments based on data quality.
3. Explore the potential to apply various quantitative assessment models ranging from indicator-based assessments to full data rich stock assessment options.
4. Select the appropriate models that will be used for the full stock assessment of each species. List assumptions and caveats with the use of the models.

Expected Publications

- Research Documents
- Proceedings

Expected Participation

- Fisheries and Oceans Canada (DFO) Science and Fisheries Management sectors
- Academics
- Other invited experts

References

DFO. 2013. Assessment of Buffalo River Inconnu (*Stenodus leucichthys*) Great Slave Lake, Northwest Territories, 1945-2009. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/045.

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APPENDIX 2. MEETING AGENDA

MULTI-SPECIES STOCK ASSESSMENT FRAMEWORK FOR GREAT SLAVE LAKE

Regional Peer Review: Ontario and Prairie Region and Arctic Region

March 14–15, 2023

Hybrid Meeting
Freshwater Institute, Winnipeg, MB and via MS Teams
Time in Central (CST)

Chairperson: Joclyn Paulic

DAY 1 – Tuesday, March 14, 2023

9:00 a.m. Opening Welcome and Meeting Introduction (Chair)

- Participant Introduction (Please be prepared with a few sentences about your background, knowledge and expertise for this meeting)

9:15 a.m. Overview of the CSAS Peer Review Process (J. Paulic)

- Terms of Reference (Chair)
- Review Meeting Agenda (Chair)

9:30 a.m. Context for the Request (Chair)

10:00 a.m. Working Paper Presentation: Lake Whitefish (Lead Authors)

10:30 a.m. Health Break

10:45 p.m. Discussion and Questions on Lake Whitefish Working Paper (Chair)

12:00 p.m. Lunch (not provided)

12:30 p.m. Working Paper Presentation: Inconnu (Lead Authors)

1:00 p.m. Discussion and Questions on Inconnu (Chair)

2:30 p.m. End of Day 1

DAY 2 – Wednesday, March 15, 2023

9:00 a.m. Summary of Day 1

9:05 a.m. Working Paper Presentation: Lake Trout (Lead Authors)

9:45 a.m. Discussion and Questions on Lake Trout (Chair)

10:30 a.m. Health Break

10:45 a.m. Summarize Changes and Outcomes for the Working Papers; Determine if Working Papers adopted as Research Documents

11:00 a.m. Review any additional outstanding comments or points of discussion

12:30 p.m. Lunch (not provided)

1:00 p.m. Identify any additional analysis and/data needed prior to future stock assessment

2:00 p.m. Summarize Meeting Participant expectations and CSAS Publication Timelines and upcoming meeting timelines

2:05 p.m. Meeting Complete – THANK YOU!

APPENDIX 3. LIST OF MEETING PARTICIPANTS

Name	Organization/Affiliation
Joclyn Paulic (Chair)	DFO Science, Ontario and Prairie Region
Kayla Gagliardi (Rapporteur)	DFO Science, Ontario and Prairie Region
Brendan Malley (Rapporteur)	DFO Science, Ontario and Prairie Region
Yamin Janjua	DFO Science, Ontario and Prairie Region
Xinhua Zhu	DFO Science, Ontario and Prairie Region
Kimberly Howland	DFO Science, Ontario and Prairie Region
Ross Tallman	DFO Science, Ontario and Prairie Region
Kevin Hedges (written review)	DFO Science, Ontario and Prairie Region
Samantha Fulton (written review)	DFO Science, Ontario and Prairie Region
Stephanie Sardelis	DFO Science, National Capital Region
Hailey Chymy	DFO Science, Ontario and Prairie Region
Daniel Enright	DFO Science, Ontario and Prairie Region
Chelsey Lumb	DFO Science, Ontario and Prairie Region
Adam Van Der Lee	DFO Science, Ontario and Prairie Region
Dave Boguski	DFO – Fisheries Management, Arctic Region
Alexis Burt	DFO – Fisheries Management, Arctic Region
Rob Young	DFO – Retired
Geoff Klein	Province of Manitoba
Darren Gillis (written review)	University of Manitoba

APPENDIX 4. DECISION TREE

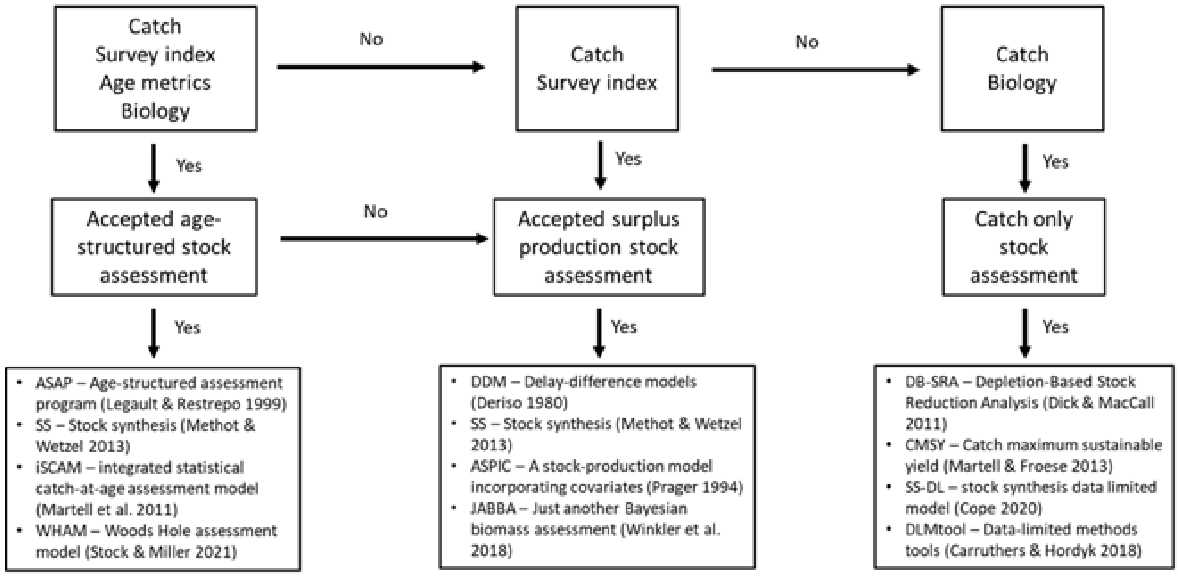

Figure A1. Decision tree for the stock assessment framework, to be used for all three species (Lake Whitefish, Inconnu, Lake Trout).