



IDENTIFICATION OF A LIMIT REFERENCE POINT AND PROPOSAL OF AN UPPER STOCK REFERENCE FOR CANADIAN FISHERY MANAGEMENT OF EASTERN GEORGES BANK (5ZJM) HADDOCK (*MELANOGRAMMUS AEGLEFINUS*)



Image: Haddock (*Melanogrammus aeglefinus*)
Credit: Fisheries and Oceans Canada

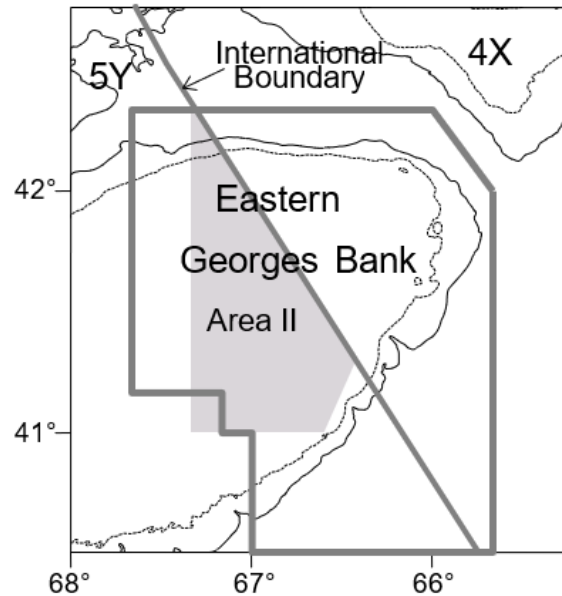


Figure 1. Eastern Georges Bank management area.

Context:

Fisheries and Oceans Canada (DFO) and the United States (U.S.) National Marine Fisheries Service (NMFS) have jointly assessed Haddock (*Melanogrammus aeglefinus*) on the eastern portion of Georges Bank (EGB) under the Transboundary Resources Assessment Committee (TRAC) peer review process since 1998. A new assessment framework for EGB Haddock was developed at the Canada/U.S. Georges Bank Haddock Research Track assessment meeting in March 2022 and subsequently used to support the provision of advice to the TMGC at the July 2022 TRAC meeting (TRAC 2022). Explicit biomass reference points for EGB Haddock were not developed by the TRAC or requested by the Transboundary Management Guidance Committee (TMGC). However, to support DFO's domestic fishery management, biomass reference points are required to implement DFO's fishery decision making framework incorporating the precautionary approach (DFO 2009) and to evaluate the status of EGB Haddock under the Canadian Environmental Sustainability Indicators (CESI) program and the Sustainability Survey (DFO 2021). Accordingly, biomass reference points were

developed using the new assessment model to support DFO's domestic fishery management requirements.

*This Science Advisory Report is from the May 2–3, 2023, Regional Peer Review on the Identification of a Limit Reference Point and Proposal of an Upper Stock Reference Point for the Canadian Fisheries Management of Eastern Georges Bank (5Zjm) Haddock (*Melanogrammus aeglefinus*). Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.*

SUMMARY

- Haddock (*Melanogrammus aeglefinus*) on eastern Georges Bank (EGB) is a Canada/United States transboundary species and is assessed by the Transboundary Resource Assessment Committee (TRAC). For Canadian domestic fishery management, biomass reference points are required to implement DFO's fishery decision-making framework incorporating the precautionary approach.
- A new statistical catch-at-age model was developed for EGB Haddock in 2022; therefore, it was necessary to provide updated advice and recommendations on biomass reference points.
- The productivity relationships for two different time periods (1931–1954, 1969–2020) were examined. The 1969–2020 time series of data was considered the most appropriate for the calculation of reference points due to the absence of evidence of productivity regime shifts and full availability of age composition data.
- B_{recover} , defined as the lowest spawning stock biomass (SSB) on record that resulted in sustained recovery to historically high levels, was determined to be the most appropriate candidate limit reference point (LRP) for EGB Haddock. B_{recover} for EGB Haddock was explicitly defined as the minimum biomass between 1991 and 1996. Using this definition, and the current model outputs, the minimum estimate of SSB occurring in 1993 is the identified LRP for EGB Haddock (8,620 mt).
- The proposed upper stock reference (USR) was calculated using the “Rago-Razor” method based on spawning stock biomass and recruitment data between 1969 and 2020 and is estimated as 26,732 mt.

INTRODUCTION

Haddock (*Melanogrammus aeglefinus*) on eastern Georges Bank (EGB) is a transboundary species, jointly assessed by Fisheries and Oceans Canada (DFO) and the United States (U.S.) National Marine Fisheries Service (NMFS) under the Transboundary Resource Assessment Committee (TRAC) peer review process. The Transboundary Management Guidance Committee (TMGC) develops guidance in the form of harvest strategies, resource sharing, and management processes for this stock. The TMGC harvest strategy was developed before the establishment of the precautionary approach framework (PA framework; DFO 2009). Explicit biomass reference points for EGB Haddock have not been developed by the TRAC or requested by the TMGC. However, in Canadian domestic fishery management, biomass reference points are required to implement DFO's fishery decision-making framework incorporating the PA framework and to evaluate the status of EGB Haddock under the Canadian Environmental Sustainability Indicators (CESI) program and the Sustainability Survey (DFO 2021).

The previous Canadian limit reference point (LRP) was developed in 2012 using outputs from the 2011 virtual population analysis (VPA) assessment model run (Wang and Van Eeckhaute, 2012). A new statistical catch-at-age model was developed for EGB Haddock at the Canada/U.S. Georges Bank Haddock Research Track peer review assessment meeting held in March 2022, and subsequently used to support the provision of advice to the TMGC at the July 2022 TRAC meeting (TRAC 2022). The addition of new data since the development of the previous LRP revealed characteristics of stock productivity not previously observed. This, together with the new model, necessitated the provision of updated advice and recommendations on reference points.

This report is focused on the identification of an LRP and proposal of an upper stock reference (USR) for Canadian fisheries management of EGB Haddock. Retrospective closed-loop simulations were conducted to evaluate candidate and alternative reference points.

ANALYSIS

Data

EGB Haddock has supported a commercial fishery since the early 1920s (Clark et al. 1982). Approximate fishery catch data is available for EGB Haddock for the time period 1931–1955 (Figure 2). The output from an illustrative VPA using this dataset and estimates of biomass, spawning stock biomass (SSB), and recruitment (R) between 1969–2021 (Figures 2 and 3) from model outputs of the 2022 TRAC EGB Haddock assessment (Wang et al. In prep.¹) were used to evaluate possible productivity regime shifts over time.

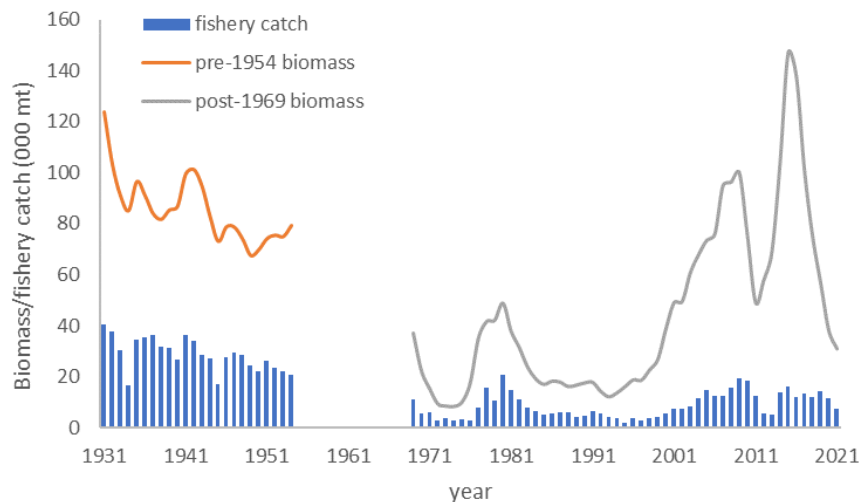


Figure 2. Fishery catch and estimated biomass of eastern Georges Bank Haddock in 1931–1954 from an illustrative virtual population analysis and 1969–2021 from the 2022 assessment.

¹ Wang Y., Regnier-McKellar, C. and Kraska, K. In Prep. Assessment of Haddock on Eastern Georges Bank for 2022. TRAC Reference Document.

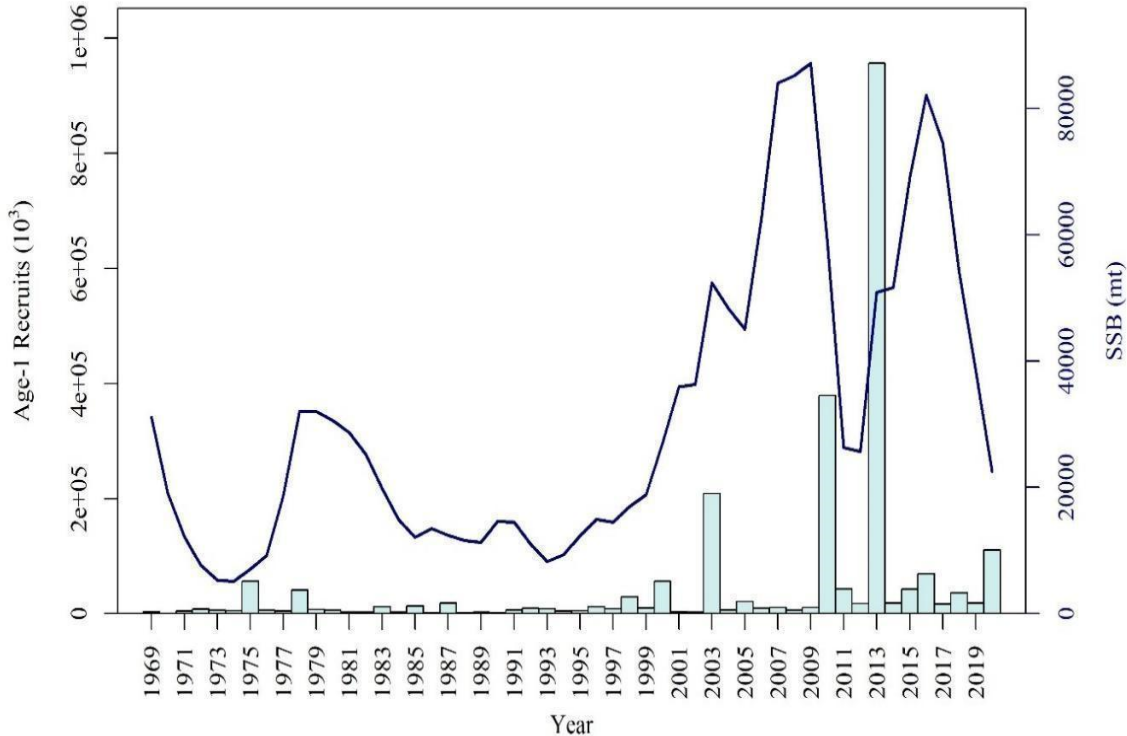


Figure 3. Estimated spawning stock biomass (SSB) and recruitment at age 1 from 1969–2021 in the 2022 eastern Georges Bank Haddock assessment. Recruitment on the left axis is noted by the bars. SSB on the right axis is noted by the solid line.

DFO guidance suggests that biomass reference points should only be estimated using information from a period of low productivity when there is no expectation that the conditions consistent with higher productivity will recur naturally or be achievable through management (DFO 2013, 2023). The population dynamics of EGB Haddock are characterized by highly variable recruitment events, density-dependent growth, and natural mortality. There have been substantial productivity changes of EGB Haddock over time. Examination of the relationship between SSB and R shows no evidence of a change in recruitment for the same level of SSB at two different time periods (1931–1954, 1969–2020) (Figure 4). Similarly, comparison of surplus production ($\text{Production}[t] = \text{Biomass}[t+1] - \text{Biomass}[t] + \text{Catch}[t]$) in different time periods does not show evidence of productivity regime shifts (Figure 4). Therefore, the longer time series (1969–2020) of data is considered more appropriate for the calculation of reference points.

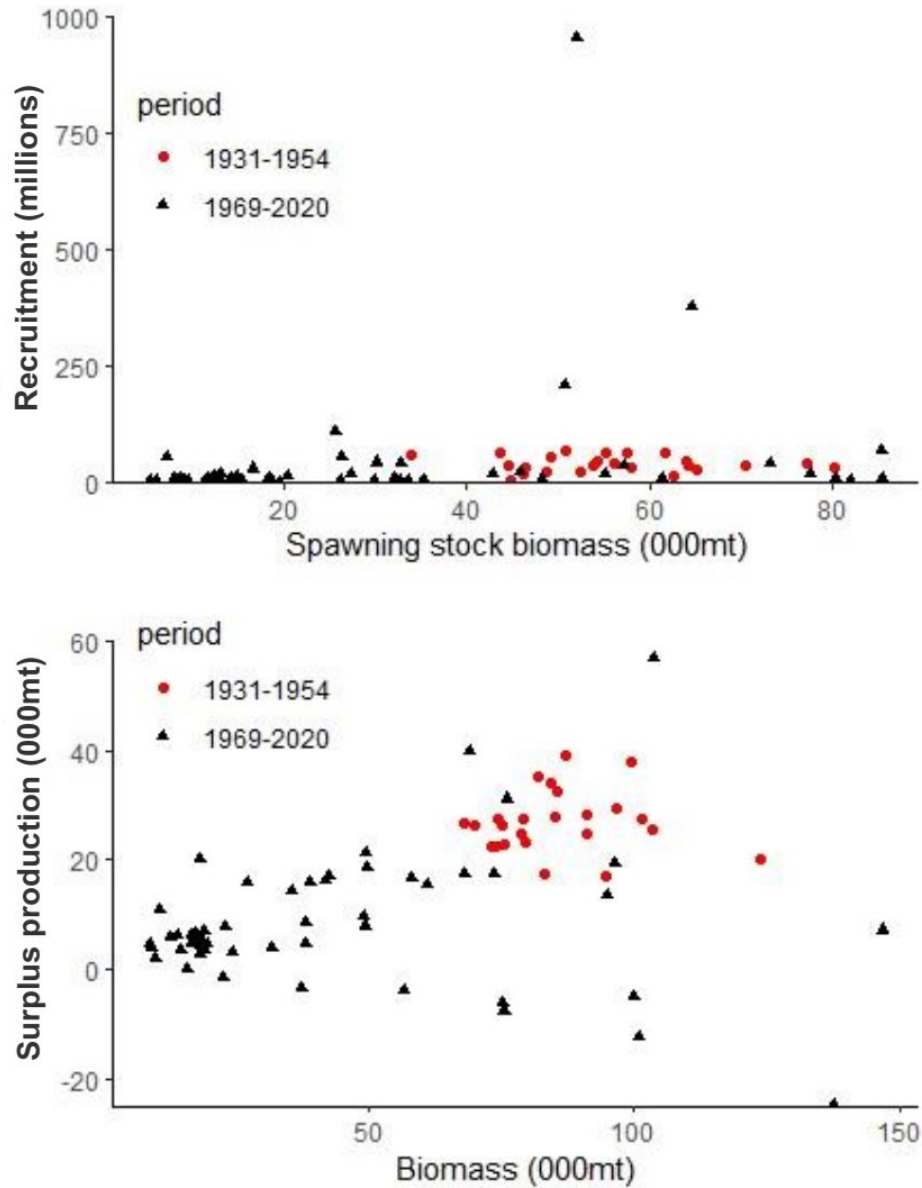


Figure 4. Relationship between spawning stock biomass (SSB) and recruitment (top panel), and biomass and surplus production (bottom panel) of eastern Georges Bank Haddock in the two time periods: 1931–1954 and 1969–2020.

Limit Reference Point

The LRP is defined as the point below which the reproductive capacity of the stock is expected to be impaired to the point of serious harm (DFO 2009). Multiple candidate LRPs were proposed for peer review, with several deemed inappropriate based on the dynamics of the stock (Wang and Carruthers In press). B_{recover} , defined as the lowest SSB on record that resulted in sustained recovery to historically high levels, was determined to be the most appropriate candidate LRP for EGB Haddock. It is also considered a proxy for recruitment overfishing, reflects productivity at low stock sizes under average conditions, and is recommended as a candidate LRP for

stocks with occasional large recruitment events (DFO 2023). When the model is rerun in future years with additional data, there may be slight variations in the model estimates of SSB. To account for this, B_{recover} for EGB Haddock was explicitly defined as the minimum biomass between 1991 and 1996. Using this definition, and the current model outputs, the minimum estimate of SSB, occurring in 1993, is the identified LRP for EGB Haddock (8,620 mt; Figure 5). B_{recover} can be used to calculate either a single estimate of stock status, $SSB_{\text{now}} / SSB_{1993}$, or a probabilistic representation of stock status, $P(SSB_{\text{now}} > SSB_{1993})$.

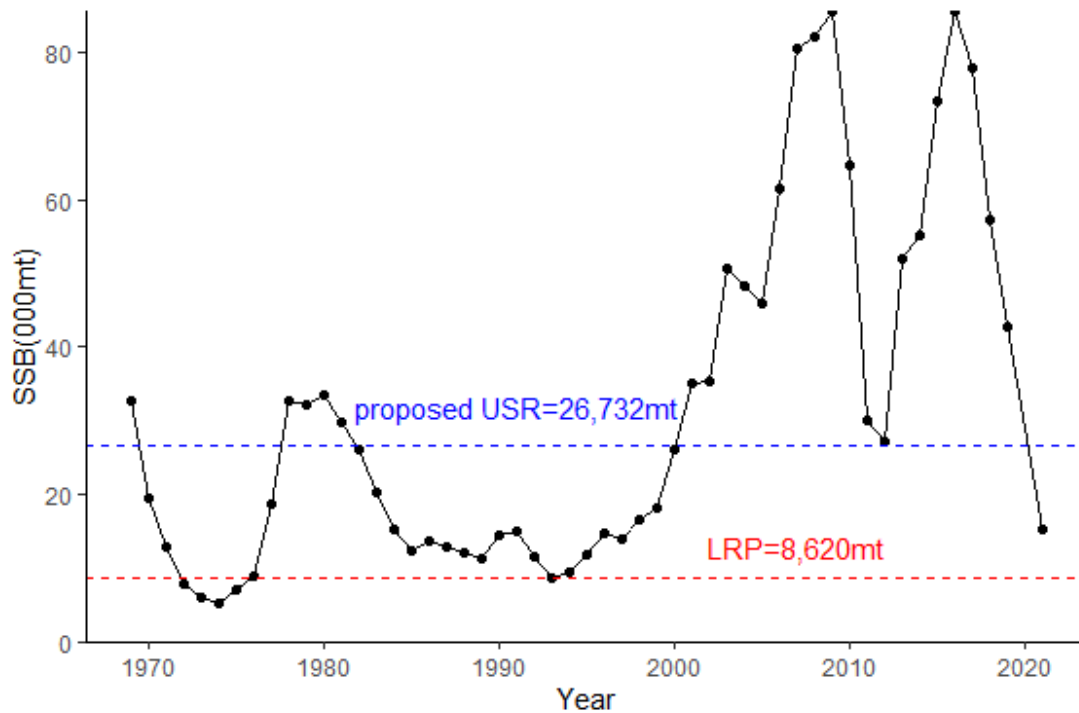


Figure 5. Time series of spawning stock biomass (SSB) of eastern Georges Bank Haddock estimated from the 2022 assessment (Wang et al. In Prep¹) with the identified limit reference point (LRP; red dashed line) and proposed upper stock reference (USR; blue dashed line).

Upper Stock Reference

The USR is defined as the boundary between the healthy and cautious zones, used in the determination of stock status under the PA framework (DFO 2009). EGB Haddock appears to have two distinct groupings in magnitude of recruitment, with large SSB generally resulting in high recruitment and small SSB generally resulting in low recruitment. The breakpoint between the two groups can be used as the USR (DFO 2004) and was estimated by minimizing the sum of mean square error of estimated recruitment points for each year between 1969 and 2021 from the mean recruitment in each group (“Rago-Razor” method, NEFSC 2008, Wang and Carruthers In press). The candidate USR for EGB Haddock is defined as the mean of the highest value in the lower SSB group and the lowest value in the highest SSB group. Using the current stock assessment (2022) maximum likelihood estimates of SSB and R, the absolute value of the USR was estimated as 26,732 mt (Figure 5). This can be used to calculate either a single estimate of status: $SSB_{\text{now}} / \text{USR}$; or a probabilistic representation of stock status: $P(SSB_{\text{now}} > \text{USR})$.

Retrospective Simulations

Historical retrospective closed-loop simulations confirmed that the biomass dynamics of EGB Haddock were strongly driven by high recruitment variability over the past two decades (Wang and Carruthers In press). If using the LRP and USR as control points in the historical fishery, retrospective closed-loop simulations showed that historical terminal biomass and average yield would be largely invariant to the implementation of alternative harvest control rules and various levels of the specified LRP and USR. Given the candidate LRP and USR, exploitation rates were substantially lower than historical levels during the 1980s and 1990s, but subsequently provided higher stock sizes and comparable catches. The candidate LRP and proposed USR provided stock rebuilding when applied starting below USR levels even during the period of low productivity (i.e., 1987–1995). The candidate LRP and USR also did not lead to stock declines much below the USR even during the period of low productivity (i.e., 1987–1995).

Sources of Uncertainty

The uncertainties that exist within the modelling framework are propagated in the value of the reference points. Reducing the sources of uncertainty (e.g., sampling error, model assumptions, input data, etc.) would improve model estimates and the precision of reference points.

CONCLUSION

B_{recover} , defined as the lowest SSB on record that resulted in sustained recovery to historically high levels, was determined to be the most appropriate candidate LRP for EGB Haddock. B_{recover} for EGB Haddock was explicitly defined as the minimum biomass between 1991 and 1996. Using this definition, and the current model outputs, the minimum estimate of SSB occurring in 1993 is the identified LRP for EGB Haddock (8,620 mt; Figure 5).

The proposed USR was calculated using the “Rago-Razor” method (NEFSC 2008, Wang and Carruthers In press) based on data between 1969 and 2020, and is estimated as 26,732 mt.

OTHER CONSIDERATIONS

The long time series of EGB Haddock data makes it possible to characterize the productivity of this stock over a wide range of spawning biomass and environmental conditions. To date, a regime shift has not been observed for this stock. However, the biomass reference points proposed in this study would need to be updated if regime shifts were detected in the future.

The LRP methods presented here do not explicitly incorporate how changes in ecosystems or environmental conditions (e.g., species interaction, climate and other factors) can affect the productivity of the EGB Haddock stock. Future research is required to fill these gaps and better meet the new requirement of DFO’s PA framework under the *Fisheries Act*’s Fish Stocks provisions (FSP) (DFO 2021).

In addition, the LRP and USR are developed for Canadian domestic fishery management requirements under the DFO PA framework (DFO 2009) and are not required for the evaluation of stock status at TRAC.

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SOURCES OF INFORMATION

This Science Advisory Report is from the May 2–3, 2023, Regional Peer Review on the Identification of a Limit Reference Point and Proposal of an Upper Stock Reference Point for the Canadian Fisheries Management of Eastern Georges Bank (5Zjm) Haddock (*Melanogrammus aeglefinus*). Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

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