



STOCK ASSESSMENT FOR LAKE TROUT (*SALVELINUS NAMAYCUSH*) IN GREAT SLAVE LAKE, NT, 2022

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*). The development of an Integrated Fisheries Management Plan (IFMP) is critical for the long-term management of GSL fisheries. There are ongoing pressures that require Fisheries and Oceans Canada (DFO) Science to provide robust science 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. Lake Trout has not been assessed in recent decades. This is the first full assessment, which includes data collected up to 2022.

This Fisheries Science Advisory Report is from the regional peer review of May 22–24, 2024 for the Stock Assessment for Lake Whitefish (*Coregonus clupeaformis*) and Lake Trout (*Salvelinus namaycush*) in Great Slave Lake, Northwest Territories, 2022. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada \(DFO\) Science Advisory Schedule](#) as they become available.

SCIENCE ADVICE

Status

- Fisheries Management Area (FMA) IW Lake Trout stock biomass in 2022 (321 tonnes [t]) is above the LRP (281 t), but below the proposed USR (450 t), placing it in the Cautious Zone with a 54% probability. There is a 43% probability that the stock is in the Critical Zone.
- The FMA IE Lake Trout stock biomass in 2022 (1,001 t) is above the LRP (695 t), but below the proposed USR (1,112 t), placing it in the Cautious Zone with a 60% probability. There is an 8% probability that the stock is in the Critical Zone.
- Due to a decrease in fishing effort since the late 1990s in FMAs II, III, IV, and V, it was not possible to estimate recent biomass and current status for these management areas. However, MSY estimates were generated and are potentially useful.
- The FMA VI was not assessed due to insufficient catch data following the closure of the area to commercial fishing in 1974.

Trends

- Fishery-dependent catch-per-unit-effort (CPUE) and weight of Lake Trout declined substantially in all areas within the first decade of commercial fishing (by the mid-1950s).
- From the 1970s to the mid-1990s, the majority of fishing effort and catch were from FMA V. Since the 2000s, most effort and catch were from FMAs IE and IW.
- Fishery independent surveys CPUE remained low from 2011 to 2021, compared to 2022, when it was higher in FMA IW. High CPUE in FMA IW in 2022 may be an anomaly.

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- Lake Trout mean weight, length, and age fluctuated without trend since 2010 in the Main Basin (FMA IW to V) and East Arm (FMA VI). Lake Trout mean age (18 vs. 14 years) and age-at-50% maturity (10 vs. 7 years) were higher in the East Arm than in the Main Basin.
- FMA IW model results indicate stock biomass increased above the LRP around the late 2000s and then levelled off. In FMA IE, biomass surpassed the LRP around the late 2000s and increased to just below the proposed USR by 2022.

Ecosystem and Climate Change Considerations

- With the ongoing trend towards warmer temperatures, there may be implications for stock structure, given different phenotypes among habitats (e.g., deep versus shallow waters). Warmer temperatures are likely to increase lake stratification, reduce available Lake Trout habitat and may impact feeding, growth, mortality, and stock productivity.
- There is a rapid restructuring of algal community composition in Great Slave Lake that is consistent with recent increases in regional air temperature, declines in ice cover, and wind speed. This aquatic ecosystem transformation could impact food web structure and functioning.
- Changes in food availability may affect the quality, quantity, and distribution of forage fish and invertebrates which are part of Lake Trout diet. Changes in forage resources may influence nutrient dynamics and the success of different life stages of Lake Trout. Changes in the food web and trophic interactions need to be better understood.

Stock Advice

- FMA IW Lake Trout is in the Cautious Zone. Stock modelling shows biomass recovered from the Critical Zone and levelled off at the current biomass. The annual harvest of Lake Trout in FMA IW exceeded MSY of 26.7 t twice in the last ten years (2018 and 2019).
- FMA IE Lake Trout is in the Cautious Zone. Stock modelling shows biomass recovered from the Critical zone and increased in the last ten years. The annual harvest of Lake Trout in FMA IE exceeded MSY of 63.1 t twice in the last ten years (2016 and 2018).
- MSY for Lake Trout in FMA II to FMA V was estimated to be 12.6 t (FMA II), 3.9 t (FMA III), 17.8 t (FMA IV), and 77.7 t (FMA V), respectively. MSY estimates should be used with caution because of decreases in fishing effort in the 2000s.
- Lake Trout MSY is well below the current Lake Whitefish and Lake Trout combined commercial quotas in all FMAs. GSL Lake Trout should be managed under a separate commercial quota rather than as a combined quota with Lake Whitefish due to differences in MSYs, life histories, habitat use, and as they are now confirmed to be in the Cautious Zone, while Lake Whitefish are in the Healthy Zone.

BASIS FOR ASSESSMENT

Assessment Details

Year Assessment Approach was Approved

Approved in 2023 in the Stock Assessment Framework CSAS Meeting (Chymy et al. In prep [a]¹)

Assessment Type

Full Assessment

Most Recent Assessment Date

1. Last Full Assessment: None
2. Last Interim-Year Update: Not applicable

Stock Assessment Approach

1. Broad category: Data-poor (Catch-based Maximum Sustainable Yield, CMSY), limited use of other model(s) (Bayesian Schaefer Model, BSM). The reported results are based on BSM for each Fishery Management Area (FMA) IW and IE, and CMSY for FMA II to V (Figure 1).
2. Specific category: Index-based (including fishery-dependent and fishery-independent indices), Surplus Production, Schaefer model with a symmetrical production curve.

CMSY++ (Froese et al. 2021) was used to estimate biomass (B) and fishing mortality (F), including the biomass (B_{MSY}) needed to support maximum sustainable yield (MSY). The Bayesian state-space Schaefer Model, BSM (Froese et al. 2017), was used for FMA IW and IE because CPUE timeseries were available for these areas. CMSY was used in FMA II, III, IV and V, because CPUE indices were not available. Only MSY estimates are reported for FMA II to V since catches in these areas violated the assumptions of the model. Stocks were not fully exploited, and there was no consistent fishing effort over the time series. For this reason, MSY values for FMA II to V may not be reliable and should be used with caution. Harvest data (metric tonnes [t]) from 1972 to 1979 to 2022 was used as the catch time series for each FMA. For FMA IW and IE, abundance indices were calculated from the fishery independent harvest study (2011–2022) as mean relative number (individuals/1,000 m²/24 h).

¹ Chymy, H., Lumb, C., Janjua, Y., and Howland, K.L. In prep (a). Great Slave Lake: Lake Trout Population Trends and Assessment. DFO Can. Sci. Advis. Sec. Res. Doc.

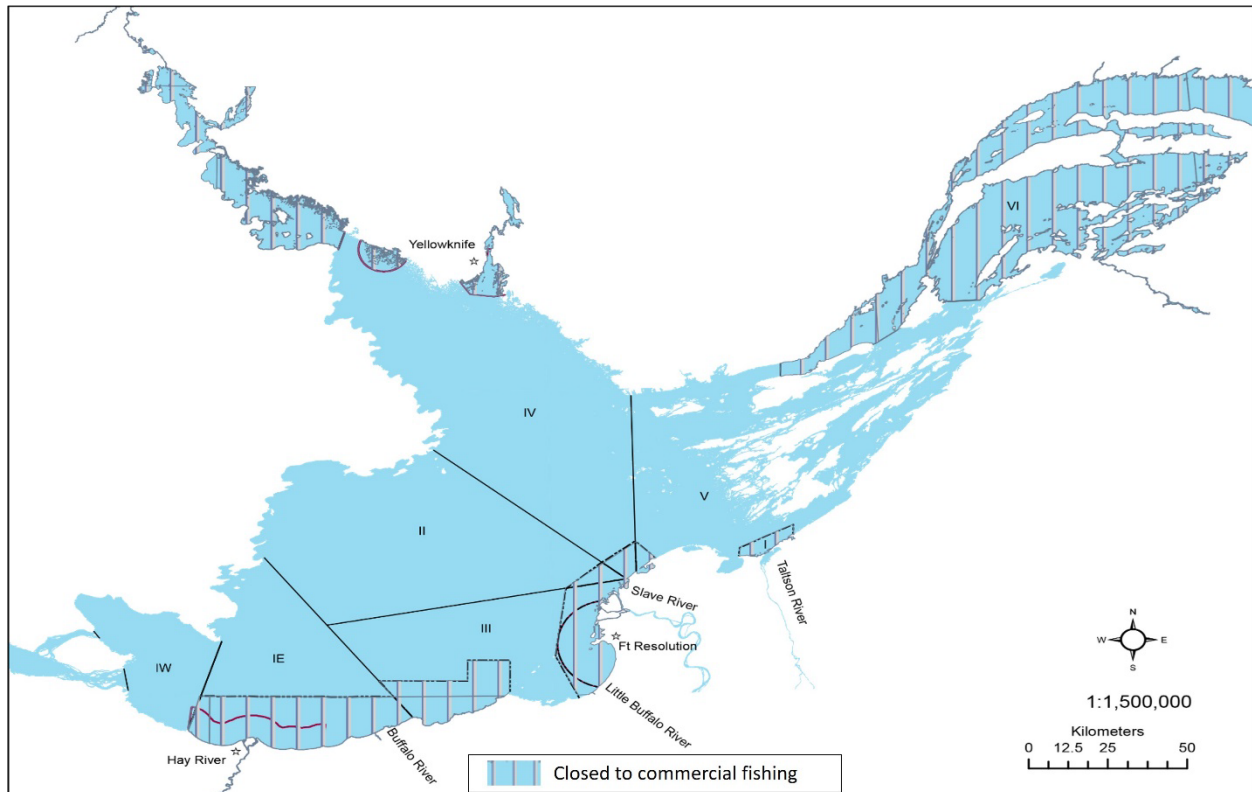


Figure 1. Great Slave Lake commercial fishing management areas (IW, IE, III–VI). Red vertical lines indicate areas closed to commercial fishing.

Stock, Ecosystem and Fishery Overview Information

Information about the stocks, ecosystem, and fishery can be found in Chymy et al. (In prep [b]²)

Stock Structure Assumption

A GSL Lake Trout genomic study was performed using samples collected between 2011 and 2021 among all seven FMAs in GSL (Bernos et al. 2024). Results showed support for at least three genetic clusters in the lake using whole-genome sequencing data. Sampled individuals from FMA IW belonged to the first genetic cluster. There were higher levels of mixing in the second and third genetic clusters, and their distributions in the lake overlapped. The second group was more likely to be harvested in the East (FMAs IV, V and VI), and the third group was more likely to be captured in the Main Basin (FMAs IE, II and III). Subdivision involving samples from the second and third genetic clusters could suggest up to five clusters. Genomics results indicated that lake topography might have influenced population structure. Limit Reference Points (LRP) have been developed for FMA IW and IE. No LRPs were developed for FMAs II, III, IV, V and VI. The FMAs are management-based units and do not represent biological units.

² Chymy, H., Janjua, Y., Lumb, C., and Howland, K.L. In prep (b). Great Slave Lake: Lake Trout Population Trends and Assessment Modelling Framework. DFO Can. Sci. Advis. Sec. Res. Doc.

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Reference Points

DFO's Precautionary Approach (PA) Policy guidance proposes default values of 0.4 and 0.8 B_{MSY} for the Limit Reference Point (LRP) and Upper Stock Reference (USR), respectively (DFO 2009). The PA Policy indicates these values are considered best practice in Canada when stock-specific values are unavailable. An LRP of 0.5 B_{MSY} was used for this assessment because catch data were used to estimate B_{MSY} (data-limited rather than data-moderate approach), and Lake Trout are not as resilient as other species to fishing pressure (DFO 2023a). We used the generic provisional policy guidance of 0.8 B_{MSY} as the proposed USR. F_{MSY} is a standard fishing pressure reference point. All the estimated Lake Trout Stock Reference Points are based on MSY. Management reference points and the stock status for Lake Trout stocks in FMA IW and IE and MSY for FMAs II, III, IV, and V are in Table 1. It was not possible to estimate other reference points or stock status for FMA II to V because of decreased fishing effort since the late 1990s, when stocks were not fully exploited.

Table 1. Stock status (B_{2022}/B_{MSY}) by Fisheries Management Area (FMA) for Lake Trout in Great Slave Lake, including Maximum Sustainable Yield (MSY), fishing pressure reference (F_{MSY}), the MSY biomass (B_{MSY}), Limit Reference Point (LRP), and the proposed Upper Stock Reference (USR). All values show 95% credible interval, where relevant, in brackets.

	FMA IW	FMA IE	FMA II	FMA III	FMA IV	FMA V
MSY (t)	26.7 (18.1–40.7)	63.1 (40.9–98.0)	12.6 (8.1–20.4)	3.9 (2.4–6.4)	17.8 (11.6–28.1)	77.7 (52.4–121)
F_{MSY}	0.047 (0.021–0.094)	0.046 (0.018–0.099)	-	-	-	-
B_{MSY}	563 (279–1,360)	1,390 (625–3,390)	-	-	-	-
LRP (0.5 B_{MSY})	281 (139–680)	695 (312–1,695)	-	-	-	-
USR (0.8 B_{MSY})	450 (223–1,088)	1,112 (500–2,712)	-	-	-	-
B_{2022}/B_{MSY}	0.57 (0.32–0.86)	0.72 (0.43–1.14)	-	-	-	-
Probability $B_{2022}/B_{MSY} > 1$	0.17%	7.4%	-	-	-	-
Probability of $B_{2022} > 0.5B_{MSY}$	56.6%	92.0%	-	-	-	-
Status	Cautious	Cautious	-	-	-	-

Data

- Harvest data (1945-1970s by basin; 1972 to 1979 to 2022 by FMA)
- Fishery sampling (1940–1960's)
- Present sampling (2010–2022)

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- East Arm summer monitoring by Łutselk'e First Nation (2019-2022)
- Main Basin summer monitoring by local communities (e.g., Kát'odeeche First Nation) and commercial harvesters (2010, 2019–2022)
- Main Basin Fish Plant Sampling (2014–2016 and 2020)
- Fall Spawner index survey (2017–2019)
- Fisheries Independent Harvest Study (2011–2022) (DFO 2015)
- Fisheries Independent Gillnet Study (2011–2022) (DFO 2023b)

ASSESSMENT

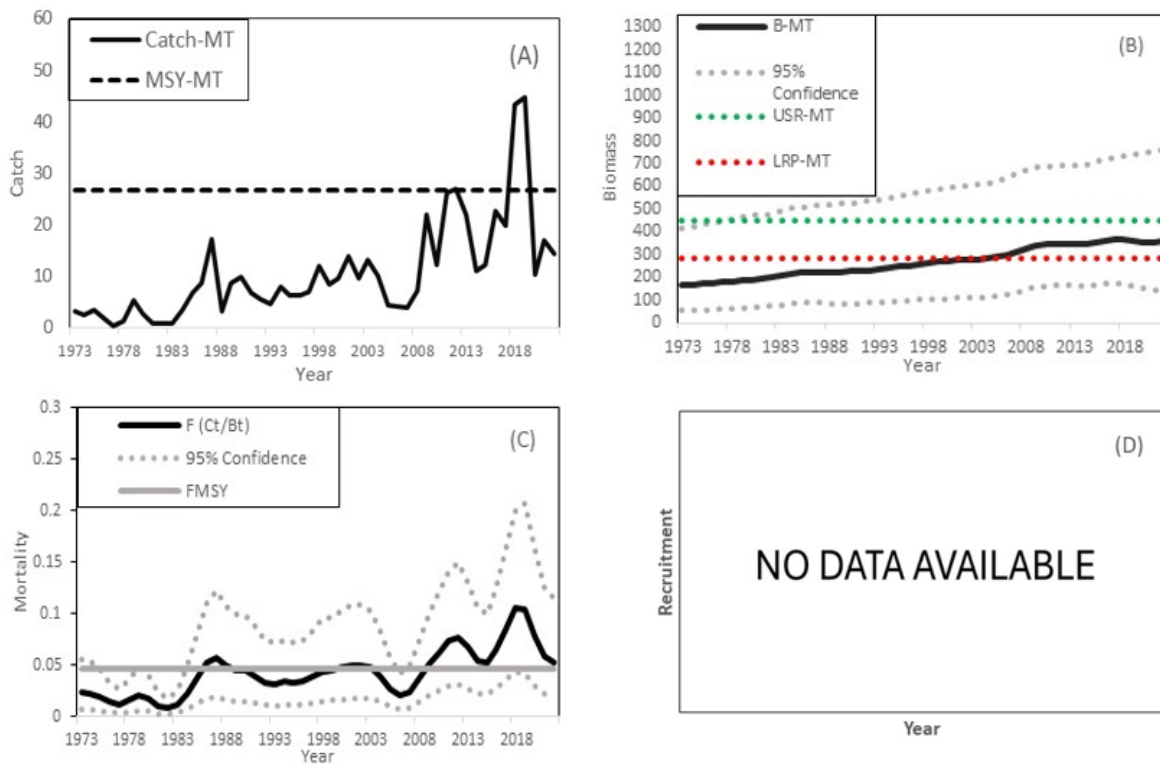


Figure 2. (A) Catch-MT (MT= metric tonnes) and Maximum Sustainable Yield (MSY-MT); (B) Stock Biomass (B-MT; in metric tonnes, MT), in relation to the Limit Reference Point (LRP-MT; red dash line) and proposed Upper Stock Reference (USR-MT; green dash line); (C) Fishing Mortality, F (harvest rate in a given year, estimated by Ct/Bt, the ratio of Catch in tonnes to Biomass in tonnes), in relation to F_{MSY} (the harvest rate that would lead to the maximum sustainable yield); (D) No information available to determine recruitment for Fisheries Management Area (FMA) IW for Lake Trout in Great Slave Lake.

Stock Status and Trends

Biomass

Results of the assessment suggest FMA IW Lake Trout biomass surpassed the estimated LRP around the late-2000's following a biomass increase and then leveled off (Figure 2B). Following recent high catches, for example in 2018, the increase in Lake Trout biomass has stalled preventing the stock from reaching a point above the proposed USR.

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Fishing Mortality

Modelling results show fishing mortality of Lake Trout was below or close to fishing mortality that would support maximum sustainable yield (F_{MSY}) for most of the time series in FMA IW (Figure 2C). Fishing mortality increased above F_{MSY} during years of high catches (2011, 2012, 2018, and 2019) and decreased during years of lower catches (2014, 2015, and 2020 to 2022).

Current Outlook

FMA IW is in the Cautious Zone. Biomass in 2022 (321 t) is above the LRP (281 t) but below the proposed USR (450 t).

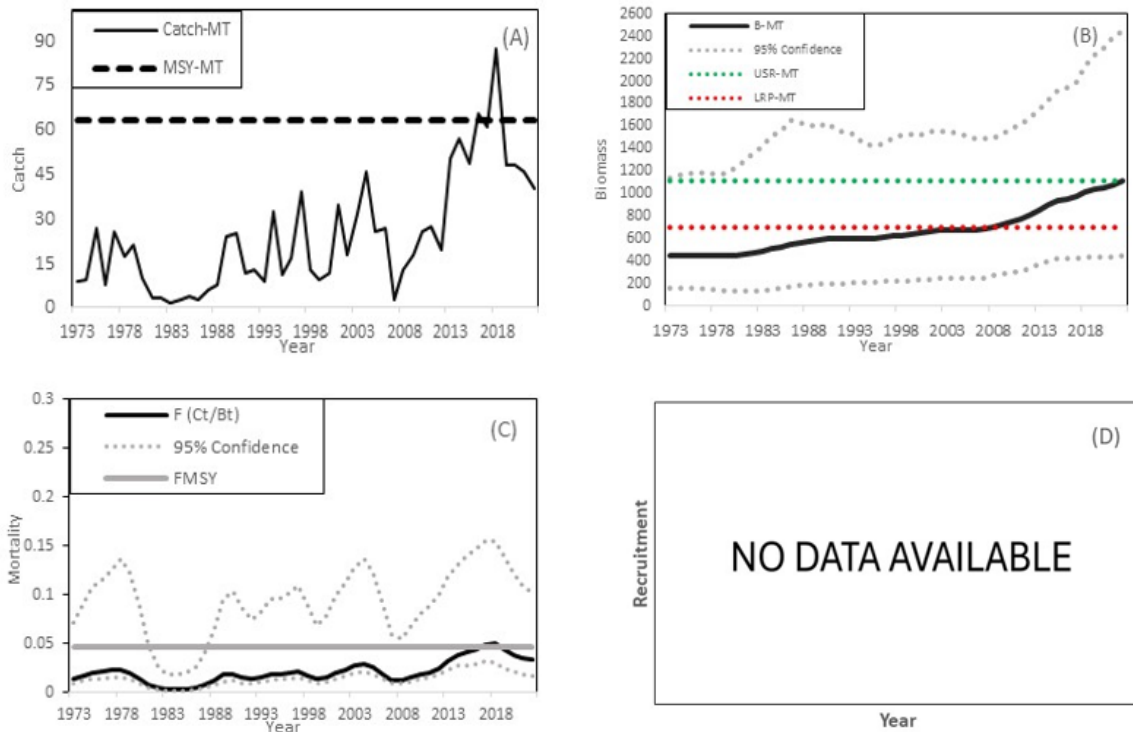


Figure 3. (A) Catch-MT (MT= metric tonnes) and Maximum Sustainable Yield (MSY); (B) Stock Biomass (B-MT; in metric tonnes MT), in relation to the Limit Reference Point (LRP-MT; red dash line) and proposed Upper Stock Reference (USR-MT; green dash line); (C) Fishing Mortality (F) (harvest rate in a given year, estimated by Ct/Bt, the ratio of Catch in tonnes to Biomass in tonnes), in relation to F_{MSY} (the harvest rate that would lead to the maximum sustainable yield); (D) No information available to determine recruitment for Fisheries Management Area IE for Lake Trout in Great Slave Lake.

Stock Status and Trends for FMA IE

Biomass

Results of the assessment suggest FMA IE Lake Trout biomass recovered above the LRP around the late 2000's, followed by an increase in stock biomass. Biomass in 2022 (1,001 t) was close to but below the proposed USR (1,112 t; Figure 3B).

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Fishing Mortality

Modelling results show fishing mortality of Lake Trout was below fishing mortality that would support maximum sustainable yield (F_{MSY}) for most of the time series in FMA IE (Figure 3C). Fishing mortality increased slightly above F_{MSY} when catches increased (2016 to 2018) and decreased when catches decreased (after 2018). Fishing mortality below F_{MSY} supported stock growth (biomass) over the time series.

Current Outlook

FMA IE is in the Cautious Zone. Biomass in 2022 is above the LRP (695 t) but still below the proposed USR (1,112 t).

Stock Trends

Harvest

Since the 1970s, Lake Trout harvest has remained at a fraction of the historical harvest, the largest of which was 1,800 t in 1949 (Figure 4). Whole lake annual catches ranged from 10 to 149 t between 1971 and 2022. Although Lake Trout is no longer the primary target of the commercial fishery, the percentage of Lake Trout in Lake Whitefish commercial harvest increased from typically less than 10% from the 1970s to 2017, to a mean of nearly 30% from 2018 to 2022. Lake Whitefish and Lake Trout are managed under a combined commercial quota for each FMA, as they have been since the beginning of the fishery.

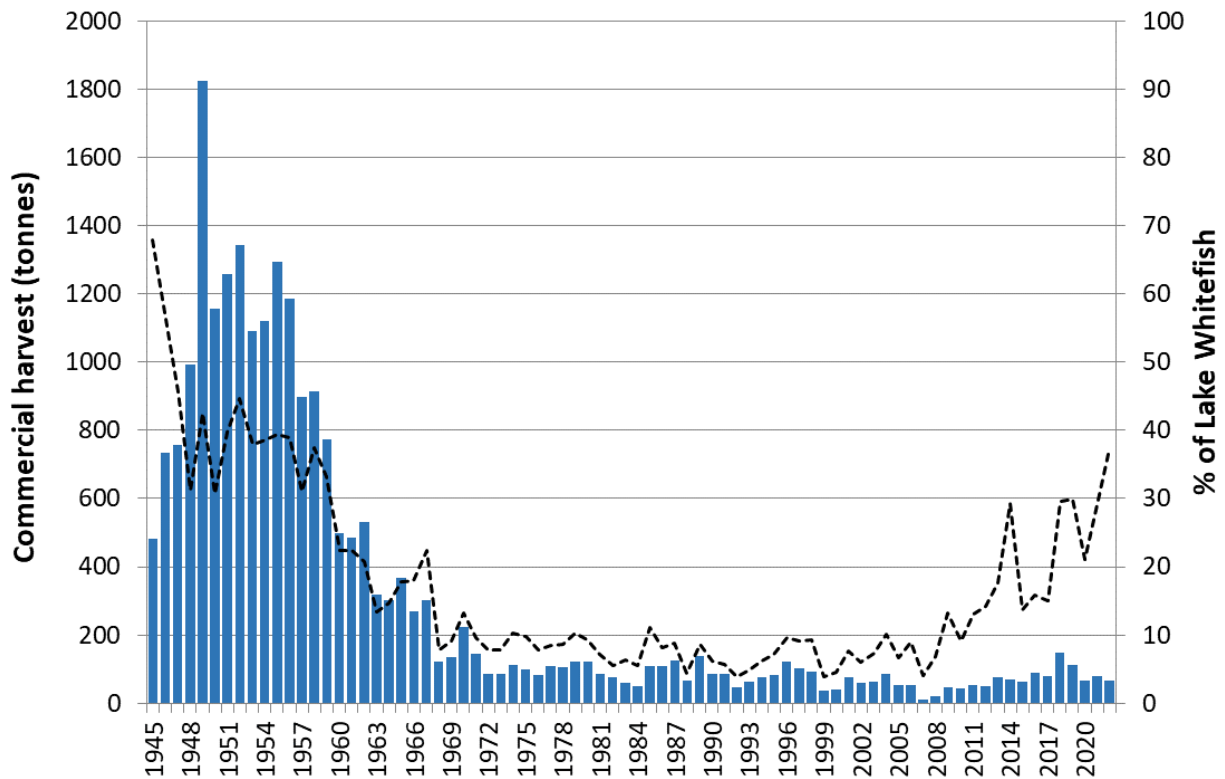


Figure 4. Lake Trout commercial harvest (catch) in tonnes in Great Slave Lake (blue bars) from 1945 to 2022; the black dash line shows Lake Trout catch as a percentage of the Lake Whitefish catch.

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Abundance

Historical sampling revealed average availability of Lake Trout (round weight of fish caught per standard 100 yard net per 24 hours) in the commercial fishery declined steeply over the first 12 years of the fishery (1945–1956). Trends in CPUE are calculated as an indicator of change in stock abundance. From fishery-independent monitoring (2011–2022), Lake Trout CPUE was relatively low (mean of less than 4 individuals or 0.5 to 11 kg/1,000 m²/24 h) except in Area IW in 2022 where values increased from 11 to 15 individuals and almost 30 kg to 60 kg, in monitoring surveys.

Weight and Age

Lake Trout average weight decreased within a decade of the start of commercial gillnetting, which began in 1945. In recent years of monitoring (2010–2022), Lake Trout mean weight has fluctuated without trend.

Mean age shows no trends over time in recent years of monitoring (2010–2022). Lake Trout mean age over all years was higher in the East Arm (18 years) than in the Main Basin (14 years), likely because of lower exploitation levels (the East Arm is closed to commercial fishing).

Unknown

There is a gap in CPUE and demographic data from 1970–2009. Recent reliable stock trajectories are not available for FMA II, III, IV and V. A complete time series (2011–2022) of logbooks CPUE analysis is not available for all management areas.

History of Management

Great Slave Lake has been divided into FMAs for most of the commercial fishery. Since 1971, the commercial fishery has been harvested with area quotas for Lake Whitefish and Lake Trout combined for seven management areas throughout the lake (IW, IE, II, III, IV, V & VI). In 1974, Area VI was closed to commercial harvesting at the start of the fishing year (November 1974). Current Lake Whitefish and Lake Trout combined commercial quotas for FMAs are shown in Table 2. Commercial harvest of Lake Trout by FMA has varied since the 1970s. Harvest was largely from FMA V until the late 1990s, when the closure of fish plants in different areas of the lake resulted in lower catches in some FMAs. Since the 2000s, harvest has been mainly from the Western Basin (FMA IW and IE).

Table 2. Current combined quota in tonnes (t) for Lake Whitefish and Lake Trout by Fisheries Management Area (FMA) in Great Slave Lake.

	FMA IW	FMA IE	FMA II	FMA III	FMA IV	FMA V
Combined Quota (t)	227.3	318.2	318.2	45.5	409.1	363.6

Ecosystem and Climate Change Considerations

Water levels on Great Slave Lake fluctuated from an extreme low in July 2019 to a record high between 2020 and 2022, followed by a historic low in summer 2023. The same was observed for the tributary rivers with historic high flows in 2021 and 2022, followed by historic lows in 2023. Zhu et al. (2017) found that Lake Trout biomass, unlike Lake Whitefish, occurred in areas of clear water in the Main Basin and was evenly distributed across different depth strata. High

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flows of tributary rivers, such as the Slave River, contribute to increased turbidity in the lake because of nutrient and particulate organic matter inputs and could affect available habitat for Lake Trout.

The number of ice-free days in the Western Basin near Hay River has increased by 21 days in 53 years (Rühland et al. 2023). Hay River air temperature has increased significantly from 1896 on average by 0.29 °C per decade (Rühland et al. 2023). Reduced ice-covered period and warming temperatures diminish the quantity and quality of overwintering habitats, which could affect Lake Trout egg survival and juvenile growth. Great Slave Lake has undergone rapid restructuring of algal community composition and transformation of the aquatic ecosystem in response to accelerated Arctic warming in the twenty-first century (Rühland et al. 2023). Warmer water temperatures resulting in reduced habitat availability for cold-water fish could disproportionately affect Lake Trout phenotypes that occupy shallow versus deep water. Recent genomic work found the genetic cluster in FMA IW was mainly caught in shallow water (15.1 ± 7.2 m) (Bernos et al. 2024). The other two clusters were more likely to be caught in the Main Basin (FMAs IE, II and III) and East Arm (FMAs IV, V and VI), and were usually caught in deeper waters (26.2 ± 18.8 m and 37.2 ± 20.7 m, respectively). A warming climate could affect Lake Trout biological characteristics, such as growth, age at maturity, fecundity, and spawning timing. However, the environmental conditions affecting Lake Trout populations in Great Slave Lake are currently unknown, in part due to limited knowledge of their habitat. Changes in food web structure and relative biomass across trophic levels may affect trophic interactions (predator-prey relationships in the food web) and require better understanding.

Projections

Modelling simulations were not conducted for future projections of these stocks. However, based on the modelling trends, the Lake Trout stock in FMA IW is likely to remain in the Cautious Zone at present harvest rates (fishing mortality above F_{MSY}). The Lake Trout stock in FMA IE is likely to grow at present harvest rates where fishing mortality is below F_{MSY} . Biomass in 2022 relative to B_{MSY} for FMA IW (0.57) and IE (0.72) was below the biomass required at MSY (B_{MSY}). Low exploitation in recent years in FMA II, III, IV and V and limited data to inform the model impede the ability to comment on future trends of stocks in these FMAs.

SOURCES OF UNCERTAINTY

Lake Trout in Great Slave Lake is considered a data-deficient fishery and as a result, the available data and associated analyses have high uncertainty. Contemporary CPUE and demographic data are available beginning in 2010 and are lacking for FMAs II, III, IV and V. Logbooks to evaluate CPUE were not available for this assessment, which makes it difficult to infer trends in catch-effort in the commercial fishery. There are uncertainties associated with Lake Trout movement during different seasons, which could influence CPUE indices. The current stock assessment neglects to consider possible differences between distinct populations of GSL Lake Trout or multiple phenotypes with potentially varied demographic rates, although research suggests the presence of different genetic clusters in the lake. One or more deep-water populations likely inhabit Great Slave Lake and could not be identified in the most recent genomic study because samples were not available below a depth of 50 meters. All the input parameters and priors used in different models, including the intrinsic population growth rate (r), initial and final stock depletion levels, are associated with uncertainty. The lack of divergence in the retrospective analyses for FMAs II, III, IV and V must be interpreted with caution. This pattern is likely due to low exploitation when catches are negligible and limited data are

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available to inform the model. Commercial catches of Lake Trout decreased in FMA II to V beginning in the late 1990s. Additional outside forces (e.g., climate change, fish freight subsidy, access to fish plants) can influence harvesters’ activities and total production, but are unable to be interpreted by the models. However, these events may help explain discrepancies in retrospective patterns. Harvest from recreational and subsistence catches is unknown, as are local sales and culls, and they are not included in this assessment. These catches are important components of the entire harvest. The environmental conditions affecting the Lake Trout stocks are currently unknown as are food web structure and relative biomass at different trophic levels that may impact trophic interactions.

Research Recommendations

Additional dedicated studies are recommended to monitor the relative abundance and demographics of Lake Trout stocks in FMAs II, III, IV and V. The development of new abundance indices and monitoring biological trends, especially for management areas with limited or no data collection and low catches, are recommended to address uncertainties and data gaps. Given Lake Trout life history and vulnerability to overfishing, regular review of the stocks is recommended. Logbook data should be analyzed to provide information on harvest trends, effort and local sales to address data gaps related to CPUE and catch. Studies on Lake Trout movement would help address some of the uncertainties with CPUE indices. Further genomic work with more samples and more sequencing coverage could clarify subdivision within the second and third genetic clusters. A mixed stock genetic analysis would support the potential management of Lake Trout stocks among management areas. Additional sensitivity analysis, for example, excluding recent years of low exploitation when catches were small in FMAs II to V, could help to improve our understanding of how MSY estimates are influenced by catches. Studies that include environmental variables in future stock assessments would provide information about the impact of climate change on Lake Trout stocks. Research into GSL Lake Trout habitat suitability and trophic interactions could help add support for the determination of reference points and safe harvesting levels for each FMA.

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