



# GREAT SLAVE LAKE INCONNU (*STENODUS LEUCICHTHYS*) STOCK ASSESSMENT, 2022

## CONTEXT

Fisheries and Oceans Canada (DFO) Fisheries Management requested that the stocks of Great Slave Lake (GSL) Inconnu (*Stenodus leucichthys*) be reviewed to assess trends in harvest, catch effort, and biological indicators, incorporate these data into population models to estimate time-series for stock status, and estimate the population abundance/biomass, sustainable harvest levels, and identify associated uncertainties and evaluate candidate reference points (Limit Reference Point [LRP], Upper Stock Reference [USR]) consistent with DFO's Precautionary Approach framework.

This Fisheries Science Advisory Report is from the regional peer review meeting of the April 17–18, 2024 on Stock Assessment for Inconnu (*Stenodus leucichthys*) 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

- The Buffalo River Inconnu stock (population) is below the calculated LRP (stock biomass = 34 tonnes [t]) with 91% probability based on data from 1971–2022. This places the stock in the Critical Zone.
- The Slave River Inconnu stock (population) is considered above the proposed USR (stock biomass = 334 t), placing it in the Healthy Zone with a 30% probability of being in the Cautious Zone based on data from 1971–2022.
- Both the Marian River and the Mackenzie River stocks could not be assessed independently due to insufficient monitoring/catch data.
- Several stocks (populations) are known to be extirpated in GSL, including spawning stocks in the Yellowknife, Taltson, Little Buffalo, and Hay Rivers.
- Inconnu in the Western Basin mixed stock (management areas IE and IW) are considered above the LRP (biomass = 143 t) with 96% probability based on data from 1971–2022 but below the proposed USR with 93% probability, placing it in the Cautious Zone.

### Trends

- Mean Catch-per-Unit Effort (CPUE) for all sex and maturity stages combined and CPUE for mature female Inconnu from spring monitoring at the mouth of Buffalo River declined from the 1970s to 2022.

- For Slave River Inconnu, trends from CPUE are uncertain; however, model results indicate biomass is increasing. Overall, there is an increase, but the modelling results show a small decrease in biomass in 2021 and 2022.
- Fishery-independent gillnet survey CPUE and biomass increased in the Western Basin mixed stock (management areas IE and IW) in 2022. Harvesters have also observed this increase.
- No trend data exists for the Marian and Mackenzie Rivers. For the Marian River, the community has observed that their Inconnu subsistence catches, which were absent at Frank Channel in the 1970s (for some duration), have increased more consistently.

### Ecosystem and Climate Change Considerations

- Spring water levels on Great Slave Lake and tributary flows have varied significantly between 2019 and 2023, which may have impacted spawning and overwintering fish habitat.
- Recent increases in regional air temperature, declines in ice cover, and wind speed may impact Inconnu's biological characteristics, such as maturity, spawning timing, fecundity, and migration.
- An aquatic ecosystem transformation in Great Slave Lake may be impacting food web structure and trophic interactions (top-down and bottom-up controls), and needs to be better understood.

### Stock Advice

- Buffalo River Inconnu is in the Critical Zone. Stock modelling shows biomass has been trending downward and harvest levels upward. Buffalo River's MSY is 11.2 t, and  $F_{MSY}$  is estimated at 0.06. The current harvest levels are estimated to exceed  $F_{MSY}$ .
- Slave River Inconnu is in the Healthy Zone. MSY for Slave River is estimated at 47.1 t, and  $F_{MSY}$  as 0.11. The present harvest level is estimated to be almost equal to  $F_{MSY}$ .
- MSY for Inconnu in the Western Basin is estimated at 51.4 t, and  $F_{MSY}$  as 0.12. Western Basin Inconnu is in the Cautious Zone, but the current harvest levels (2022) are estimated to be close to  $F_{MSY}$ .
- It is recommended that Great Slave Lake Inconnu be managed as separate stocks based on natal rivers using stock indicators (at rivers) and apportioning the commercial fishery catches based on the annual or biennial genetic sampling for commercial fishery mixed stock analysis.

## BASIS FOR ASSESSMENT

### Assessment Details

#### Year Assessment Approach was Approved

Approved in 2023 during the Stock Assessment Framework CSAS meeting (Janjua et al. In prep<sup>1</sup>).

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<sup>1</sup> Janjua, Y., Tallman, R., Enright, D., and Howland, K. In prep. Testing of Models to Determine Trends and Status of Great Slave Lake Inconnu Stocks. DFO Can. Sci. Advis. Sec. Res. Doc.

**Assessment Type**

Full Assessment

**Most Recent Assessment Date**

1. Last Full Assessment: Buffalo River Stock only - March 30–31, 2010 (DFO 2013)
2. Last Interim-Year Update: Buffalo River Stock only - May 1, 2014 (DFO 2014)

**Stock Assessment Approach**

1. Broad category: Data-poor (CMSY, BSM), model ensemble (Stock Synthesis). The reported results are from BSM.
2. Specific category: Index-based (including fishery-dependent and fishery-independent indices), Surplus Production, Statistical catch-at-age.

CMSY++ (Froese et al. 2021), along with the Bayesian state-space implementation of the Schaefer surplus production model (BSM) (Meyer and Millar 1999), was used to estimate the time series of biomass (B) and fishing mortality (F), including the biomass from which maximum sustainable yield can be obtained (BMSY). Stock synthesis (SS) modelling was also used to create an age-structured population dynamics simulation by combining several sub-models. Although multiple models were used to provide advice that accounts for uncertainty, the ensemble methods approach was not used (model averaging), and BSM modelling results were used for advice and Reference Point estimates because it was considered the most appropriate model as identified in the Stock Assessment Framework CSAS Meeting (Janjua et al. In prep<sup>1</sup>). Stock synthesis recruitment modelling results are used to show trends in recruitment.

**Stock Structure Assumption**

From 2017 to 2018, the temporal and spatial genetic population structure in the Great Slave Lake river systems was examined (Wiens et al. 2021). Bayesian clustering analysis found evidence of five discrete genetic groups corresponding to four fishery stocks including: including lower/upper Mackenzie, Slave River, Buffalo River, and Marian River. Philopatry to river systems has influenced the contemporary genetic structure of three stocks (Buffalo River, Marian River and Slave River) that use Great Slave Lake.

**Reference Points**

The DFO's PA Policy guidance provides default values of 0.4 and 0.8  $B_{MSY}$  for the Limit Reference Point (LRP) and Upper Stock Reference (USR), respectively (DFO 2009). Without stock-specific LRP or other rationales, we used generic provisional policy guidance of 0.4  $B_{MSY}$  as LRP and 0.8  $B_{MSY}$  as USR.  $F_{MSY}$  is a standard fishing pressure limit reference point. All the estimated Inconnu Stock Reference Points are based on Maximum Sustainable Yield (MSY). Management Reference Points and the stock status assessed for the Buffalo River, Slave River Stocks, and Western Basin Inconnu are in Table 1 and Figure 1.

Table 1. Reference Points (with Confidence Levels) and Status for the Buffalo and Slave River stocks and the Western Basin Management Area for Inconnu. Note: \*if  $B < 1/2 B_{MSY}$ , the model adjusts the  $F_{MSY}$  linearly (0.06); if  $B > 1/2 B_{MSY}$ ,  $F_{MSY} = 0.12$  for the Buffalo River Inconnu.

	Buffalo River	Slave River	Western Basin
<b>MSY</b>	11.2 (6.9–20.4)	47.1 (37.2–75.1)	51.4 (38.2–74.2)
<b>F<sub>MSY</sub></b>	0.06* (0.05–0.08)	0.11 (0.08–0.15)	0.12 (0.08–0.16)
<b>B<sub>MSY</sub></b>	92.8 (57.7–180.7)	418 (291–625)	448 (312–689)
<b>LRP (0.4 B<sub>MSY</sub>)</b>	37.1 (23.1–72.3)	167 (116–250)	143 (125–276)
<b>USR (0.8 B<sub>MSY</sub>)</b>	74.2 (46.1–144.5)	334 (233–500)	358 (250–551)
<b>B<sub>2022</sub>/B<sub>MSY</sub></b>	0.25 (0.13–0.50)	0.87 (0.53–1.25)	0.71 (0.48–0.98)
<b>Status</b>	Critical	Healthy	Cautious

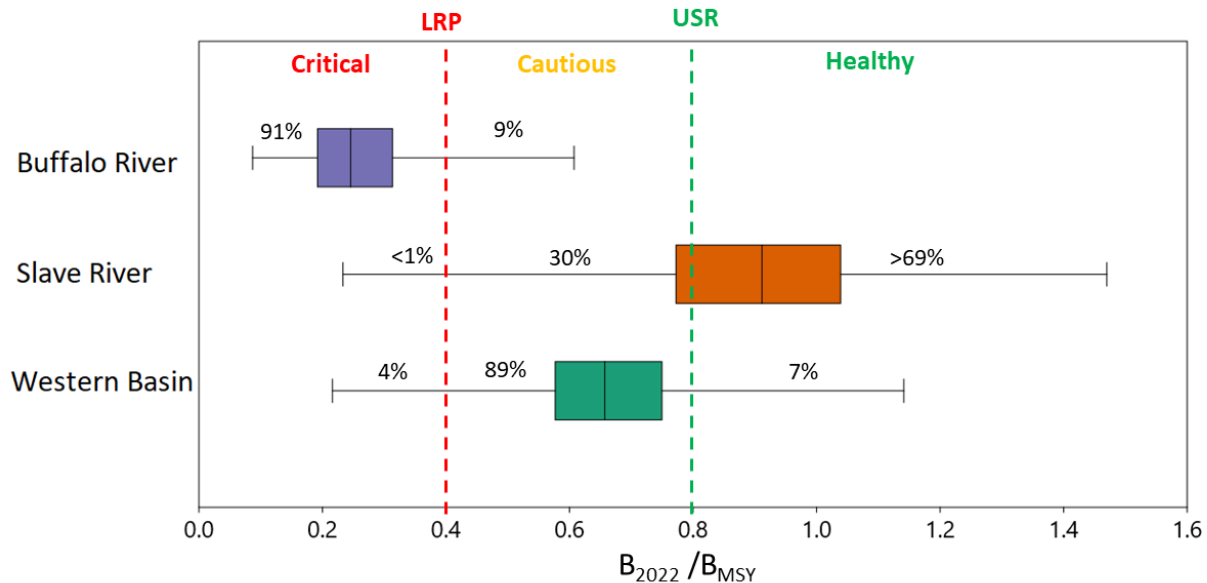


Figure 1. The stock status of Buffalo River Inconnu, Slave River Inconnu, and Western Basin Inconnu, with probabilities of being in the status zones based on BSM modelling.

**Data**

**Harvest Data (1945–2022):** The fish plants have provided commercial harvest records as round weight; since 1972, harvest has been provided management area-wise.

**Mixed Stock Analysis Data:** Mixed stock analysis data (2017–2018) was used to estimate river stock catch date.

**Buffalo River Mouth Spring Monitoring (Intermittent 1947–2008, Regular 2011–2022):** In the spring (May–June), a gillnet sampling program at the mouth of the Buffalo River is conducted independently of the commercial fishery for biological assessment and CPUE analysis.

**Slave River Fall Monitoring (2018–2022):** Slave River Inconnu was monitored from 1981 to 1983, 1993 to 1994, and since 2018, a Slave River Inconnu fall monitoring program in collaboration with local domestic fishers for biological assessment and CPUE analysis.

**Inconnu Fisheries Independent Harvest Study 2009–2022:** Initiated in 2009 to document Inconnu's spatial and temporal distribution in GSL management Areas throughout the summer months.

**Fisheries Independent Gillnet Study (FIGS) 2011–2022:** Initiated in 2011, using multi-mesh gillnets to monitor the relative abundance and biomass of multispecies in different management areas of GSL.

## ASSESSMENT

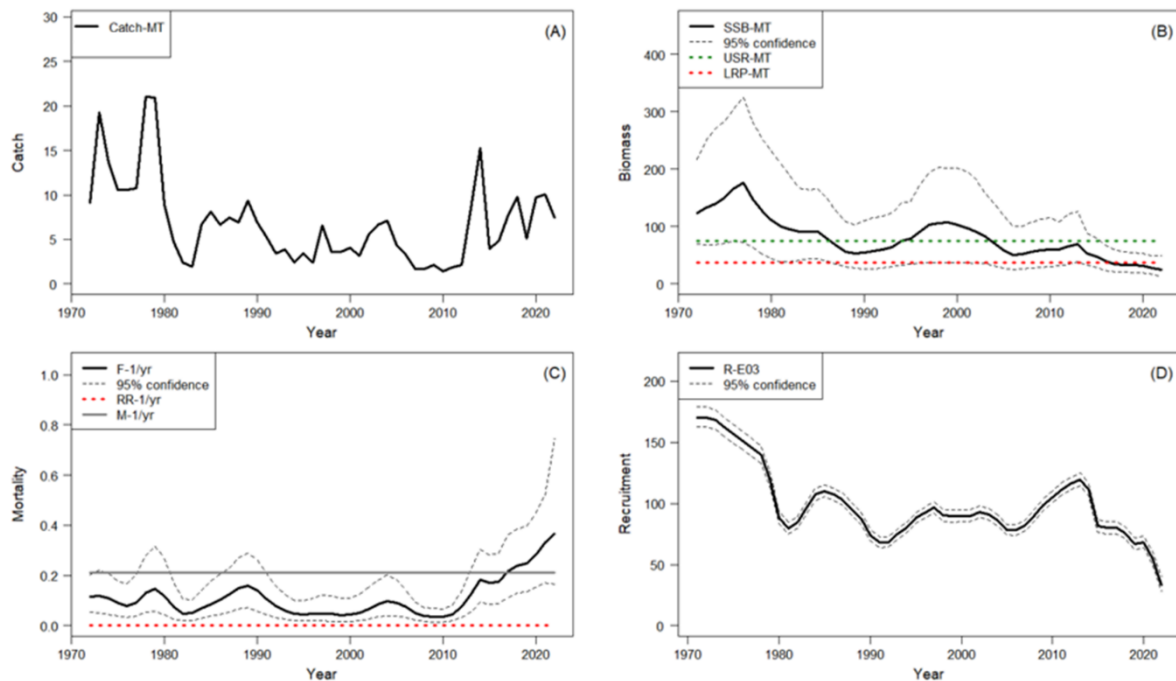


Figure 2. Buffalo River Inconnu, (A) Catch in metric tonnes (MT), (B) Stock Biomass (B) in relation to the Limit Reference Point (LRP) and Upper Stock Reference (USR), (C) Fishing Mortality (F) in relation to Natural Mortality (M), and (D) Recruitment (R). Confidence levels are shown as grey dashed lines.

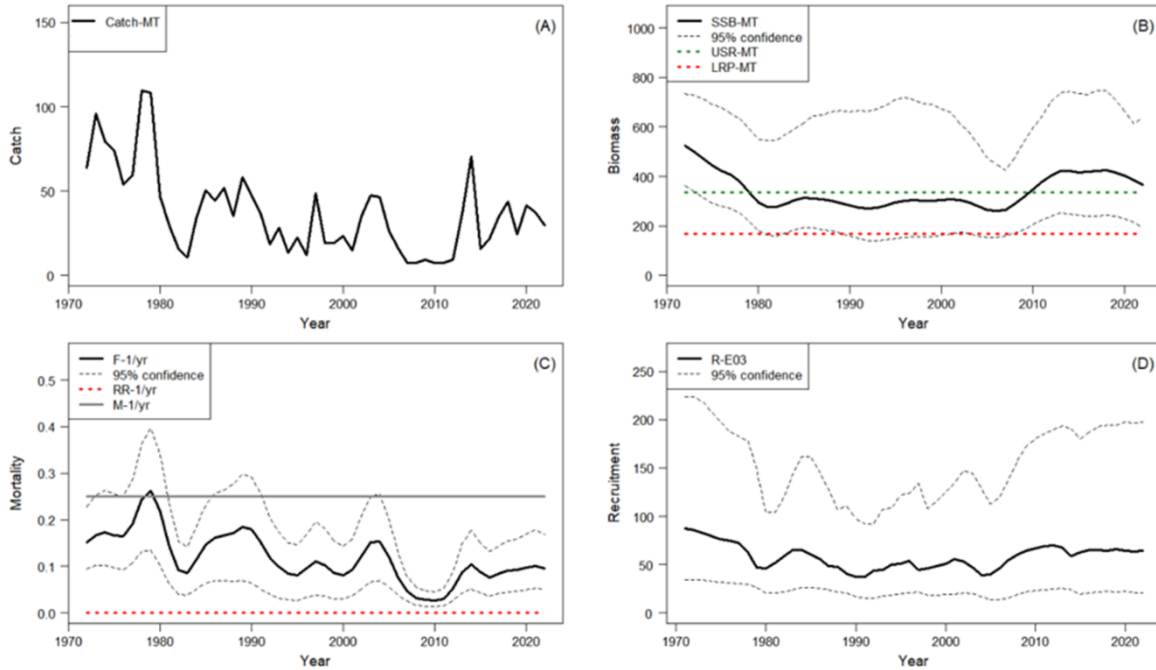


Figure 3. Slave River Inconnu, (A) Catch in metric tonnes (MT), (B) Stock Biomass (B) in relation to the Limit Reference Point (LRP) and Upper Stock Reference (USR), (C) Fishing Mortality (F) in relation Natural Mortality (M), and D) Recruitment (no data available). Confidence levels are shown as grey dashed lines.

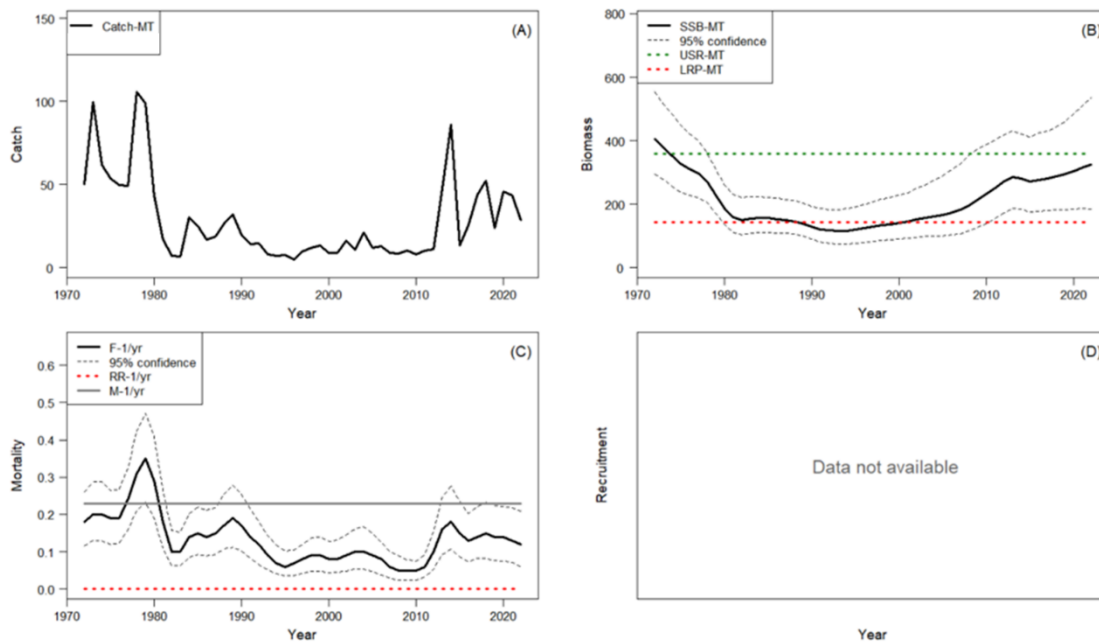


Figure 4. Western Basin Inconnu, (A) Catch in metric tonnes (MT), (B) Stock Biomass (B) about the Limit Reference Point (LRP) and Upper Stock Reference (USR), (C) Fishing Mortality (F) in relation to Natural Mortality (M), and D) Recruitment (no data available). Confidence levels are shown as grey dashed lines.

## Biomass

Buffalo River biomass dropped below the LRP in mid-2010 after a high harvest in 2014. The biomass observed in 2022 was the lowest value in the time series (Figure 2). Slave River Inconnu biomass was below the Upper Stock Reference until 2009 but has been in a healthy zone since 2010 (Figure 3). Western Basin (mixed stock) Inconnu biomass was low in the 1990s (likely in the critical zone) but continuously increased since 2000 (Figure 4).

## Fishing Mortality

Modelling results show the mean fishing mortality rate of Buffalo River Inconnu has been above FMSY since 2014 (Figure 2). This high F coincided with the increase in total removals from 2013 onwards. In 2022, F was the highest (0.36 & 0.32) as estimated by BSM and SS, respectively. The mean fishing mortality of Slave River Inconnu is equal to or below the FMSY in recent years.

## Recruitment

SS modelling shows that recruitment in the Buffalo River Inconnu stock has declined since 2015 and has remained near all-time lows in recent years (Figure 2). Recruitment in Slave River Inconnu has increased since 2004 and has remained stable in recent years (Figure 3).

## Harvest

Except for the first year (1944–1945), the Inconnu harvest tracks the Lake Whitefish catch at around 5% (Figure 5). However, exceptions to high catches occurred in 1978, 1979, 2014, and recent years (2021–2023, Figure 5). Since 2013, there has been a sharp increase in Inconnu catches, and the percentage of Inconnu to Lake Whitefish catches. In 2014, Inconnu catches were 55% of the Lake Whitefish catches, 34% in 2021, and 58% in 2023. During these years, Lake Whitefish harvest increased slightly, but the Inconnu harvest increased greatly.

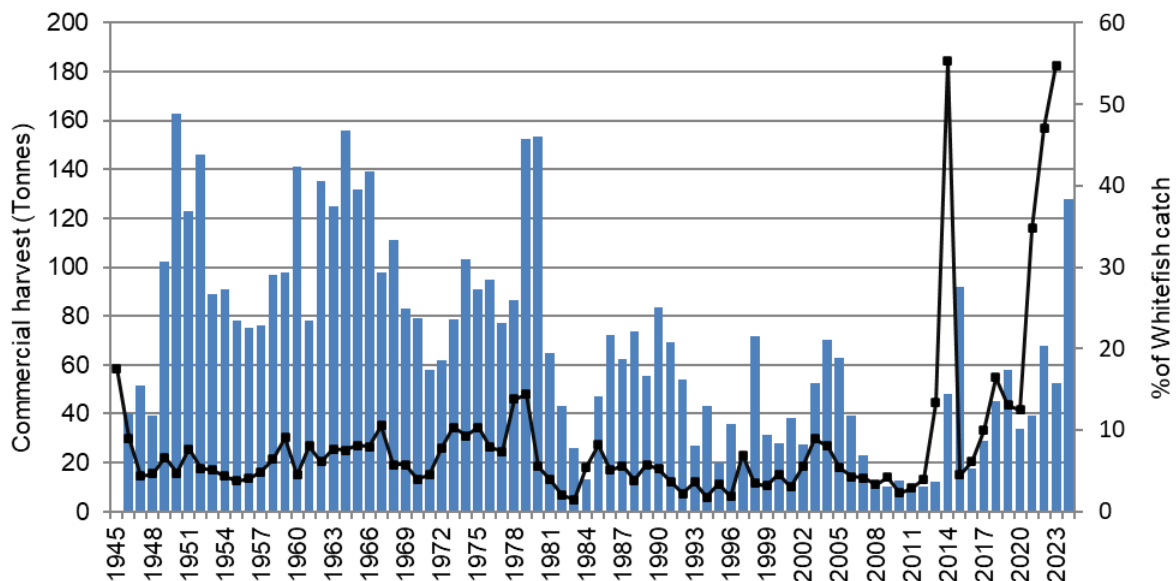


Figure 5. Total (in metric tonnes; t) Inconnu commercial harvest (catch) in Great Slave Lake (blue bars) with the percent of Lake Whitefish catch (black line).

## Abundance

Trends in CPUE are calculated as an indicator of change in stock abundance. CPUE from fishery-independent monitoring (1977–2022) at the Buffalo River mouth has declined from 20 fish/50 m/h in 1977 to 1 fish/50 m/h in 2022, or 11 mature females/50 m/h in 1977 to 0.4 mature females/50 m/h in 2022. There was an increase in CPUE in 2013, but it declined again after a high commercial catch in 2014. Slave River Inconnu fall monitoring CPUE declined in 2021 and 2022 and then increased in 2023.

Western Basin fishery-independent harvest survey CPUE (2009–2023) showed the highest mean recorded in 2023, while the lowest mean CPUE was recorded in 2017, with no trend in the data.

## Length and Age

In Buffalo River, the mean fork length was highest at the onset of the fishery in 1947 (745 mm) and reached its lowest point in 1980 after a high harvest in 1979. Through the 1990s, the mean fork length increased and was stable relative to earlier decades. From 2013, the mean fork length was greater than previously, but there was no trend. In recent years, the variance of the length distribution was greater, likely indicating a mix of recruits and older fish with no length class > 10%. For Slave River, fork length seems to be lower after 2020.

For Buffalo River Inconnu, older fish have been observed since 2018. However, in recent years, mean age and age structure have fluctuated without a trend. The year class of 2006 was strong and persisted in the data from age 7 to age 10 as the dominant year class. In Slave River, the mean age in recent years fluctuated only slightly, and no trend was observed. Modal age has fluctuated between 8 and 9 years.

## Marian and Mackenzie River Stocks

Historical and recent stock trajectories are unavailable for Marian River and Mackenzie River stocks. A complete time series (2011–2023) of logbook CPUE analysis is unavailable for all management areas.

## History of Management

Since 1971, the commercial fishery has been harvested with area quotas for seven management areas throughout the lake (IW, IE, II, III, IV, V & VI). Commercial fisheries used bottom set gillnets of 140 mm mesh size until 1977 and 133 mm stretched mesh size from 1977 to 1997. In 1997, commercial mesh size was lowered to 127 mm, however, harvesters still use 133 mm mesh to reduce disentangling time. The Buffalo River Inconnu stock was depleted in the late 1970s. In June 1983, concern for the Buffalo River stock led to the first closure zone being established by DFO Fisheries Management. Since then, DFO Fisheries Management has prohibited commercial fishing for all species in several areas along the south shore of GSL to protect the Buffalo River stock. Some management areas are closed year-round, while others are closed seasonally or by quota limit (Variation Order) closures. In 2010, DFO Science provided advice on the status of the Buffalo River Inconnu stock, whether management actions (closure zones) were effective, and where future research needs were required. The lower stock status reference point was set at two mature female Inconnu per 50 meters net per hour at Buffalo River mouth in spring (DFO 2013). DFO Science, through a Canadian Science Advisory Secretariat (CSAS) process (DFO 2014), recommended that Zones A and B remain closed to commercial fishing to avoid a high risk to Buffalo River Inconnu sustainability.

Inconnu harvest in GSL has varied since commercial fishing was initiated in 1945. Commercial catches ranged from a maximum of 163,000 kg in 1948–1949 to a minimum of 9,500 kg in 2009–2010. Area-wise catch data are available from 1972–2023. In 1979–1980, Inconnu catches increased abruptly. Since 2013, there has been an increase in Inconnu catches and 2023 Inconnu catches are the highest on record after 1980. Up to 2004–2005, a reasonable portion of the Inconnu catch was coming from Area V. Currently, most commercial fisheries in GSL occur in IE and IW. There is no commercial quota for Inconnu in these Great Slave Lake management areas. The lower removal reference rate for Buffalo River Inconnu was set at 10,000 kg (DFO 2013) for Area 1E, 1W, II and III. As a mixed stock fishery, management implements variation orders for closure if 30,000 kg Inconnu is caught in Area IE. However, until 2022, it has only been implemented twice, in 2017 and 2021.

### **History of Freshwater Habitat Impacts**

The Taltson River stock may have been extirpated after the Taltson dam was built in 1966. Hydroelectric development on the Slave River (Bennett Dam on the tributary River) likely impacted Inconnu since fish could not move upstream during high water events before dam installation. The construction of the Bluefish Hydro Facility Dam in the 1940s may have been a contributing factor to the Yellowknife River stock extirpation along with commercial fisheries. In 2018, at the request of the Fish and Fish Habitat Protection Program (FFHPP), DFO Science reviewed an offsetting plan for Inconnu stocking in the Yellowknife River. It is recommended that the concept of Inconnu egg stocking should be a part of a larger integrated fisheries management plan for Inconnu and should be considered from an ecosystem perspective.

### **Ecosystem and Climate Change Considerations**

Water levels on GSL went from extremely low in July 2019 to the highest on record between 2020 and 2022 and then a historical low in the summer of 2023. The same was true for the tributary rivers, which had historically high flows in 2021 and 2022, followed by a historical low in 2023. These changes may impact Inconnu spawning and overwintering habitats. The number of ice-free days in the West Basin near Hay River has increased to around 21 days in 53 years. Hay River air temperature has increased significantly from 1896 by an average of 0.29 °C per decade (Rühland et al. 2023). There is a rapid restructuring of the algal community composition and aquatic ecosystem transformation in GSL, consistent with recent increases in regional air temperature, declines in ice cover, and wind speed (Rühland et al. 2023). Warming climate in GSL may impact Inconnu's biological characteristics, such as age at maturity, fecundity, spawning timing, and migration behaviour. However, potential effects of climate change on Inconnu cannot currently be identified due to a lack of data and knowledge about their habitat. Changes in the food web structure and relative biomass at different trophic levels may impact trophic interactions (top-down and bottom-up controls) and need to be better understood, especially in changing fisheries. Janjua and Tallman (2015) used an ecosystem-level modelling simulation that incorporated a 25% reduction in overall fishing effort, over 20 years, which showed a 28% increase in Inconnu biomass.

### **Projections**

Modelling simulations were not conducted to forecast future projections for these stocks. However, based on the modelling trends, Buffalo River Inconnu will remain in the Critical Zone, and stock biomass will continue decreasing at the present harvest levels. Based on the modelling trends, Slave River Inconnu biomass may decrease at the present harvest levels.

## BYCATCH

The GSL fishery is multi-species, and generally, fishing methods and gears in commercial fisheries are imperfect for all other fish species. Bycatch species are either sold through FPMC, retained or culled. In the 2022 commercial harvest, the relative proportion of Northern Pike (*Esox lucius*) was 6%, similar to its relative abundance in the Main basin (Zhu et al. 2017). Therefore, the risk level of the pike bycatch is low. Burbot (*Lota lota*) culls in Areas 1E & 1W are high, almost 7% of the total commercial catch. However, considering its comparatively high relative biomass (14%), it is considered at low risk. Tullibee (*Coregonus artedii*) are caught in commercial gillnets and are culled (6 t in 2022). However, considering its relatively high biomass (7%), this is likely low risk. Sucker (*Catostomus catostomus*, *Catostomus commersonii*) catches are almost 5% of the total commercial catch, but because of their high relative biomass (11%), the risk level is low. Inconnu are currently managed as a bycatch fishery by DFO.

## SOURCES OF UNCERTAINTY

Inconnu in GSL is considered a data-deficient fishery, and as a result, the available data and further analysis are highly uncertain. Annual changes in monitoring dates, shifts in the aggregation timing, and mixed stock at the Buffalo River mouth may impact spring CPUE data. Buffalo River Inconnu ageing has been done using scales and, more recently, by otoliths, resulting in uncertainty regarding growth models and mortality rates. The CPUE and biological data time series for Slave River are relatively short. Biological and abundance information on the Marian River and Mackenzie River Inconnu stocks is missing. This assessment does not fully include subsistence and domestic harvests, and local sales. Complete logbook data is not available for analysis of harvest and abundance. The genetic baseline is not fully understood, and there exists uncertainty around whether all stocks are represented; a few may represent an admixed population. Mixed stock genetic analysis is based on two years of data, and historical and current stock structures may differ. Mixed stock genetic analyses are unavailable for Area V. There are related uncertainties with stock movements during the fishing season. Because of uncertainties with trends and biological parameters, all the input parameters and priors used in different models, including carrying capacity  $k$ , intrinsic population growth rate  $r$ , stock catch, and depletion level, are associated with uncertainty. The environmental conditions affecting the Inconnu stocks are currently unknown. The impact of an increase in Inconnu biomass on other fish species, especially lake whitefish, is also unknown.

## Research Recommendations

New studies are recommended to monitor the relative abundance and biological trends of Marian River and Mackenzie River Inconnu stocks. Logbook and historical data should also be analyzed to provide additional information on harvest trends, local sales, relative abundance and CPUE. These will address some of the uncertainties and data gaps identified above with the four Inconnu stocks in GSL and will help develop a longer time series for trend analysis and modelling. Fresh baseline genetic analysis and mixed stock genetics using modern genomics techniques are required to analyze and manage these Inconnu stocks properly. Collecting monthly mixed stock fishery genetics samples from all management areas during the fishing season and analysis on an annual or biennial basis is recommended. A similar analysis may be conducted on historical samples available in archives to address uncertainties related to the genetic analysis identified above. Extension of the ongoing GSL telemetry study into the Mackenzie River may also address uncertainty with movement and proportion of Mackenzie River Inconnu stocks. Further studies on the scale to otolith age conversion will help address uncertainty with age-based analysis before 2011. Including climate variables in future stock assessment modelling for more comprehensive forecasting of climate change impacts on stocks

is also recommended. Further studies on an ecosystem approach to consider the impact of change in stock biomass on trophic interactions are also recommended.

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**THIS REPORT IS AVAILABLE FROM THE:**

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ISSN 1919-5087

ISBN 978-0-660-99132-0 Cat. No. Fs70-6/2026-017E-PDF

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Department of Fisheries and Oceans, 2026

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Correct Citation for this Publication:

DFO. 2026. Great Slave Lake Inconnu (*Stenodus leucichthys*) Stock Assessment, 2022. DFO  
Can. Sci. Advis. Sec. Sci. Advis. Rep. 2026/017.

*Aussi disponible en français :*

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en 2022. Secr. can. des avis sci. du MPO. Avis sci. 2026/017.*