# SHRIMP FISHING AREAS (SFA) 4–6 NORTHERN SHRIMP (*PANDALUS BOREALIS*) STOCK ASSESSMENT IN 2023

## CONTEXT

The Fisheries Resource Management sector of Fisheries and Oceans Canada (DFO) has requested the assessment of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas (SFAs) 4, 5, and 6 as the basis for harvest advice for the 2024/2025 fishing season (*Pandalus borealis* [Integrated Fisheries Management Plan]). Northern Shrimp in SFA 6 is prescribed under Section 6 of the *Fisheries Act*.

This Science Advisory Report is from the March 12–15, 2024 Regional Peer Review on the Stock Assessment for Northern Shrimp (*P. borealis*) in SFAs 4, 5, and 6 for the 2024–25 Fishing Season. 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

- **SFA 4:** The 2023 spawning stock biomass (SSB) index is above the Upper Stock Reference point (USR) with a 68% probability, with the stock remaining in the Healthy Zone.
- **SFA 5:** The 2023 SSB index is above the Limit Reference Point (LRP, with a 99% probability), but below the USR (with a 60% probability), moving the stock from the Healthy Zone to the Cautious Zone.
- **SFA 6:** The 2023 SSB index is below the LRP with a greater than 99% probability, with the stock remaining in the Critical Zone.

### Trends

- **SFA 4:** There have been general increases in biomass indices from time-series (2005–23) lows in 2018. Fishable biomass (FB) and SSB indices increased by 2% and 13% respectively from 2022 to 2023.
- **SFA 5:** There have been general decreases in biomass indices and they are currently amongst the lowest values in the time series (1996–2023). FB and SSB indices decreased by 17% and 8% respectively from 2021 to 2023.
- **SFA 6:** FB and SSB indices have remained at or near time-series (1996–2023) lows without trends since 2016. The FB index did not change from 2021 to 2023, and the SSB index decreased by 13% from 2021 to 2023.

### Ecosystem and Climate Change Considerations

- The Newfoundland and Labrador (NL) ocean climate varies on near-decadal timescales with cooling and warming phases known to impact ecosystem productivity. The current warming

phase of the climate has been ongoing since about 2018 and has likely contributed to the improved conditions that have been observed at the lower trophic levels (i.e., phytoplankton, zooplankton).

- The NL bioregion continues to experience overall low productivity conditions, with total biomass well below pre-collapse levels (late-1980s), and has returned to a finfish dominated structure. Due to lack of data, conditions in 2G (SFA 4) are unknown.
- Under current ecosystem conditions, fishing and predation have been potential drivers of the stock in 2H (~SFA 5), while predation has been the stronger potential driver in 2J3KL (~SFA 6–7).
- Per capita net production of shrimp in 2J3KL remains lower in recent years than in the late-2000s. This trend is likely associated with impacts from predation, fishing, and ocean climate. No major changes in per capita net production of shrimp would be expected within the next 1–3 years based on these associations.

### Stock Advice

- The application of conversion factors to account for new survey vessels resulted in a revision of the biomass and exploitation rate indices (ERIs) in SFA 5 and 6 (1996–2021), and recalculation of the LRPs and USRs.
- The new vessels generally catch more shrimp than the *CCG Needler* and fewer shrimp than the *CCG Teleost*. These differences in catchability impact biomass indices and therefore the interpretation of past ERIs and calculations of current ERIs. The impact of this change represents annual changes of past FB indices' values (1996–2021) ranging from -7.4–18.9% for SFA 5 (median of -7.1%), and ranging from -6.6–21.7% for SFA 6 (median of -1.0%).
- **SFA 4:** The ERI ranged between 6.8% and 36.7% from 2005/06 to 2022/23 and the preliminary ERI was 10.8% in 2023/24. If the Total Allowable Catch (TAC) is taken in 2023/24, the ERI would be 18.4%.
- **SFA 5:** The ERI ranged between 6.6% and 31.5% from 1997 to 2022/23 and could not be calculated for 2023/24 due to no survey occurring in 2022. If the 2023/24 TAC is maintained and taken in 2024/25, the ERI would be 25.9%.
- **SFA 6:** The 2018 rebuilding plan states a maximum ERI of 10% while the stock is in the Critical Zone. If the 2023/24 TAC is maintained and taken in 2024/25, the ERI would be 10.7%.

## BASIS FOR ASSESSMENT

### Assessment Details

- **Year Assessment Approach was Approved:** 2007 (DFO 2007)
- **Assessment Type:** Full assessment
- **Most Recent Assessment Date:**
  - Last Full Assessment - February 2023, SFA 4 only. (DFO 2024a)
  - February 2022, SFA 4–6. (DFO 2023a)

## Assessment Approach

1. Broad Category: Index-based
2. Specific category: Index-based (including fishery-dependent and fishery-independent indices)

The assessment follows the framework established by DFO (2007). Catch data from the DFO fall multi-species survey (SFA 5 and 6) and Northern Shrimp Research Foundation – DFO (NSRF) summer trawl survey (SFA 4) are spatially expanded to produce biomass indices. Trends in fishery performance were inferred from TAC, commercial catch-to-date, fisheries catch per unit effort (CPUE), and fishing patterns. A detailed description of the survey history, survey design, and biomass calculations can be found in Orr and Sullivan (2013).

Relevant physical and biological oceanographic information is provided based on Atlantic Zonal Monitoring Program (AZMP) and Northwest Atlantic Fisheries Organization (NAFO) Scientific Council Standing Committee on Fisheries Environment (STACFEN) analyses (Bélanger et al. 2022, Cyr et al. 2022a; Cyr et al. 2022b, DFO 2023b).

Relevant information on broader fish community focusing on status and trends of fish functional groups, diet composition of key fish predators, and estimations of food consumption is provided by the NL Ecosystem Research Program (Koen-Alonso and Cuff 2018, NAFO 2021). Analyses focusing on shrimp production, predation, fishing pressures, and predation mortality index are also included, as well as analyses looking at potential drivers of per capita net shrimp production (DFO 2016, DFO 2017). The examination of the sustainability of aggregated catches at the functional ecosystem level is based on the approach used by NAFO (Koen-Alonso et al. 2022, NAFO 2022).

Preliminary results from a collaborative research project by Canadian Association for Prawn Producers/Northern Coalition/Marine Institute provided additional information on predator diets and consumption for SFA 4.

## Stock Structure Assumption

**Stock overview information:** Orr and Sullivan (2013) and DFO (2023a)

It is recognized that Northern Shrimp are distributed broadly over the Northwest Atlantic Ocean, including SFAs 4–6, and that these areas are connected through larval dispersal. Rates of exchange of adults are less understood. Preliminary research demonstrates localized genetically-distinct pools that may be linked to smaller-scale oceanographic profiles (i.e., gyres). These linkages need to be considered to interpret dynamics within and among assessment areas. (Orr and Sullivan 2013; DFO 2023a).

SFAs 4–6 are management-based stock units for which LRPs have been developed, but they do not represent a biological unit. The biological unit is recognized to be larger than management scales and caution in interpreting and applying stock status information at the management scale is warranted (Orr and Sullivan 2013; DFO 2023a).

## Reference Points

Northern Shrimp reference points in the Precautionary Approach (PA) Framework were developed using proxies, relatively consistent with guidance in the DFO PA Framework (DFO 2009). The reference point values were recalculated in 2024 for SFAs 5 and 6 after adjusting the biomass index estimates using conversion factors from the DFO comparative fishing

program. Reference points are presented in Tables 1 (SFA 4), 2 (SFA 5), and 3 (SFA 6). The history of the development of the reference points is outlined in the Integrated Fisheries Management Plan (IFMP) and Research Doc. (Le Corre et al. (in prep[1]).

*Table 1. Reference points for Northern Shrimp in SFA 4.*

| Reference Point | Description | Value |
|---|---|---|
| **Limit Reference Point (LRP)** | 30% of the geometric mean of female SSB over the productive period (2005–09), a proxy for $B_{MSY}$, DFO (2018b). | 19,100 t |
| **Upper Stock Reference (USR)** | 80% of the geometric mean of female SSB over the productive period (2005–09), a proxy for $B_{MSY}$, DFO (2018b). | 51,000 t |
| **Removal Reference (RR)** | NA | - |
| **Target (TRP)** | NA | - |

*Table 2. Reference points for Northern Shrimp in SFA 5.*

| Reference Point | Description | Value |
|---|---|---|
| **Limit Reference Point (LRP)** | 30% of the geometric mean of female SSB over the productive period (1996–2001), a proxy for $B_{MSY}$, DFO (2018a). | 14,900 t |
| **Upper Stock Reference (USR)** | 80% of the geometric mean of female SSB over the productive period (1996–2001), a proxy for $B_{MSY}$, DFO (2018a). | 39,700 t |
| **Removal Reference (RR)** | NA | - |
| **Target (TRP)** | NA | - |

*Table 3. Reference points for Northern Shrimp in SFA 6.*

| Reference Point | Description | Value |
|---|---|---|
| **Limit Reference Point (LRP)** | 30% of the geometric mean of female SSB over the productive period (1996–2003), a proxy for $B_{MSY}$, DFO (2018a). | 78,800 t |
| **Upper Stock Reference (USR)** | 80% of the geometric mean of female SSB over the productive period (1996–2003), a proxy for $B_{MSY}$, DFO (2018a). | 210,000 t |
| **Removal Reference (RR)** | NA | - |
| **Target (TRP)** | NA | - |

[1] Le Corre, N., Baker, K.D., Coffey, W., Malayny, C., and Sullivan, D. In Prep. Assessment of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 4-6 in 2023. DFO Can. Sci. Advis. Sec. Res. Doc.

## Data

- NSRF annual trawl survey (SFA 4 shrimp: 2005–23; Ecosystem: 2018–22)
- DFO Fall multi-species trawl survey data (SFA 5–6 shrimp: 1996–2023; NL Ecosystem Research Program analyses: 1981–2023)
- Newfoundland & Labrador comparative fishing data (2021–23)
- DFO AZMP (SFA 5–6, 1998–2023)
- NASA Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua Ocean Color observation (2003–23).
- Commercial catch data from observer-at-sea databases (SFA 4–6; 1979–2023)
- Commercial catch data from logbook databases (SFA 4–6; 1998–2023)
- Commercial catch data from Atlantic Quota Monitoring System (AQMS) (SFA 4–6; 1977–2023)
- Newfoundland and Labrador Climate Index and its sub-indices (Cyr and Galbraith 2021; 1950–2023)

## Data changes

- Commercial catch data for 2023–24 are considered incomplete as the season is not officially closed until March 31, 2024. Data were pulled on February 9, 2024.
- The DFO Fall multi-species trawl survey was not completed in 2022. The absence of these data prevented the calculation of the 2023–24 ERI in SFA 5 and 6.
- The application of conversion factors (DFO 2024b) to account for new DFO multi-species survey vessels resulted in a revision of the biomass and ERIs in SFA 5 and 6 (1996–2021), and recalculation of the LRPs and USRs (details in OTHER MANAGEMENT QUESTIONS).

# ASSESSMENT

## Historical and Recent Stock Trajectory and Trends – SFA 4 *P. borealis*

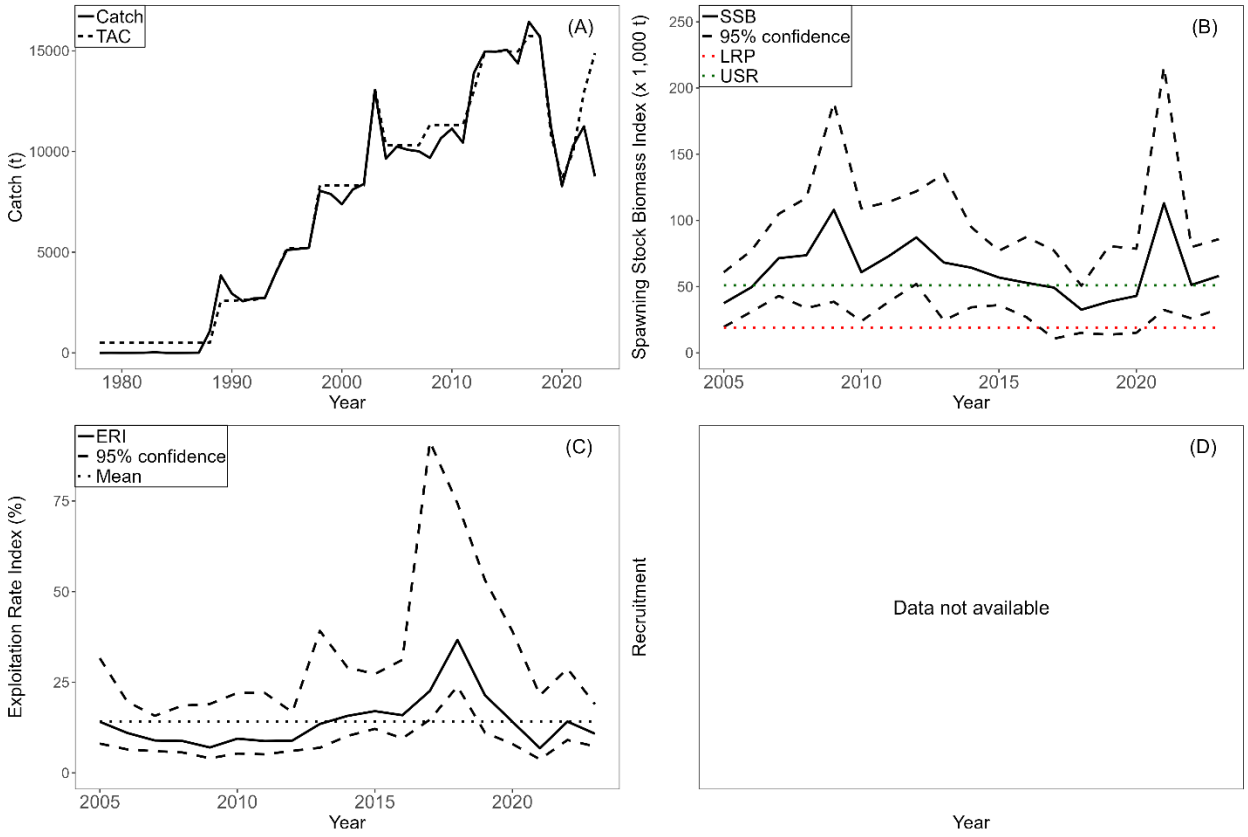


*Figure 1. Northern Shrimp in SFA 4. (A) Catch (t) and Total Allowable Catch (t) by year (note that data for 2022/23–2023/24 are incomplete), (B) Spawning Stock Biomass Index (SSB, x 1,000 t) by year in relation to the Limit Reference Point (LRP; 19,100 t) and Upper Stock Reference (USR; 51,000 t), (C) Exploitation rate index (%), (D) Recruitment could not be estimated for this stock.*

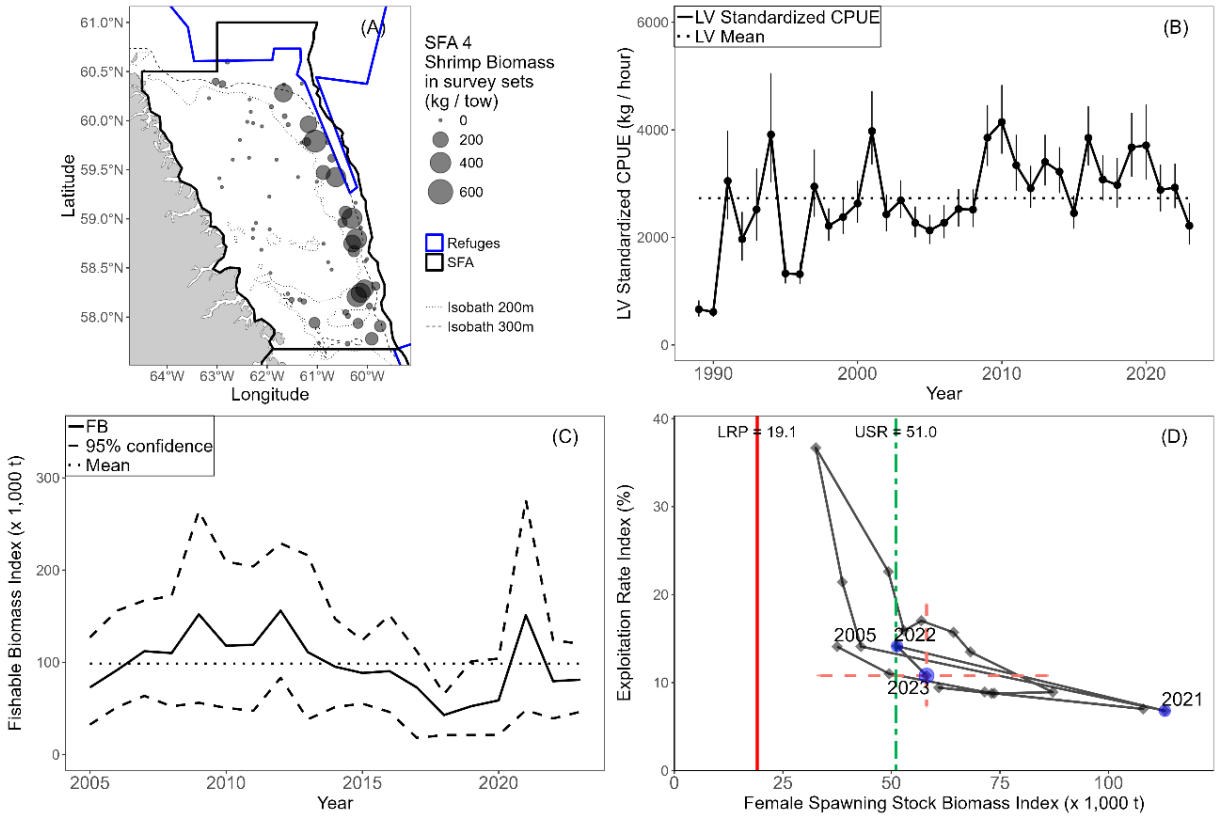


*Figure 2. Additional indicators for Northern Shrimp in SFA 4. (A) Map of the survey northern shrimp catch in 2023 (kg / tow), (B) Standardized large vessel CPUE (kg / hour), (C) Fishable Biomass Index (x 1,000 t), (D) IFMP PA Framework with ERI (%) versus female SSB index (x 1,000 t). Data point labels denote management year; the last three years are represented with blue dots and the red cross indicates 95% confidence intervals for the summer 2023 female SSB index (horizontal line) and the 2023/24 ERI (vertical line).*

### Fishery

Total catch in 2023/24 was 8,759 t, 59% of the 14,886 t TAC (preliminary AQMS data as of February 9, 2024) (Figure 1a). TAC was increased from 12,944 t in 2022/23 (87% taken) to 14,886 t in 2023/24.

Standardized large-vessel CPUE varied without trend over 1989–2023/24, but has had a declining trend since 2020/21 and was below the long-term mean in 2023/24 (Figure 2b).

### Biomass

Despite unusually high values in 2021, both the FB and female SSB recent trends suggest continued increases from a historic low in 2018 (Figure 1b).

The FB in 2023 (81,100 t; range 95% confidence intervals [CI]: 46,300 to 120,000 t; Figure 2c) remained stable (+2%) relative to the 2022 value and remained below the long-term mean (2005–22; 98,500 t). The SSB in 2023 (58,100 t; range 95% CI: 33,200 to 85,900 t; Figure 1b) increased (+13%) relative to the 2022 value but remained below the long-term mean (2005–22; 62,900 t).

Similar to most survey years, in 2023, the highest concentrations of Northern Shrimp catch in SFA 4 were found in a relatively continuous band within 201–300 m strata (68%) (Figure 2a).

The relative catchability between the four fishing vessels used for the survey in SFA 4 is unknown, leading to potential additional uncertainty around biomass indices that are not accounted for in the assessment (see Sources of Uncertainty section for more details).

### Exploitation

The ERI ranged between 6.8% and 36.7% from 2005/06 to 2022/23 (Figure 1c). As of February 9, 2024, the reported ERI for 2023/24 was 10.8% with 59% of the total allowable catch (TAC) taken. Should the entire 2023/24 TAC of 14,886 t be taken, the ERI would be 18.4%.

### Current Outlook

The 2023 Northern Shrimp SSB is above the USR (Figure 1b and 2d), within the Healthy Zone, with a 68% probability.

## Historical and Recent Stock Trajectory and Trends – SFA 5 *P. borealis*

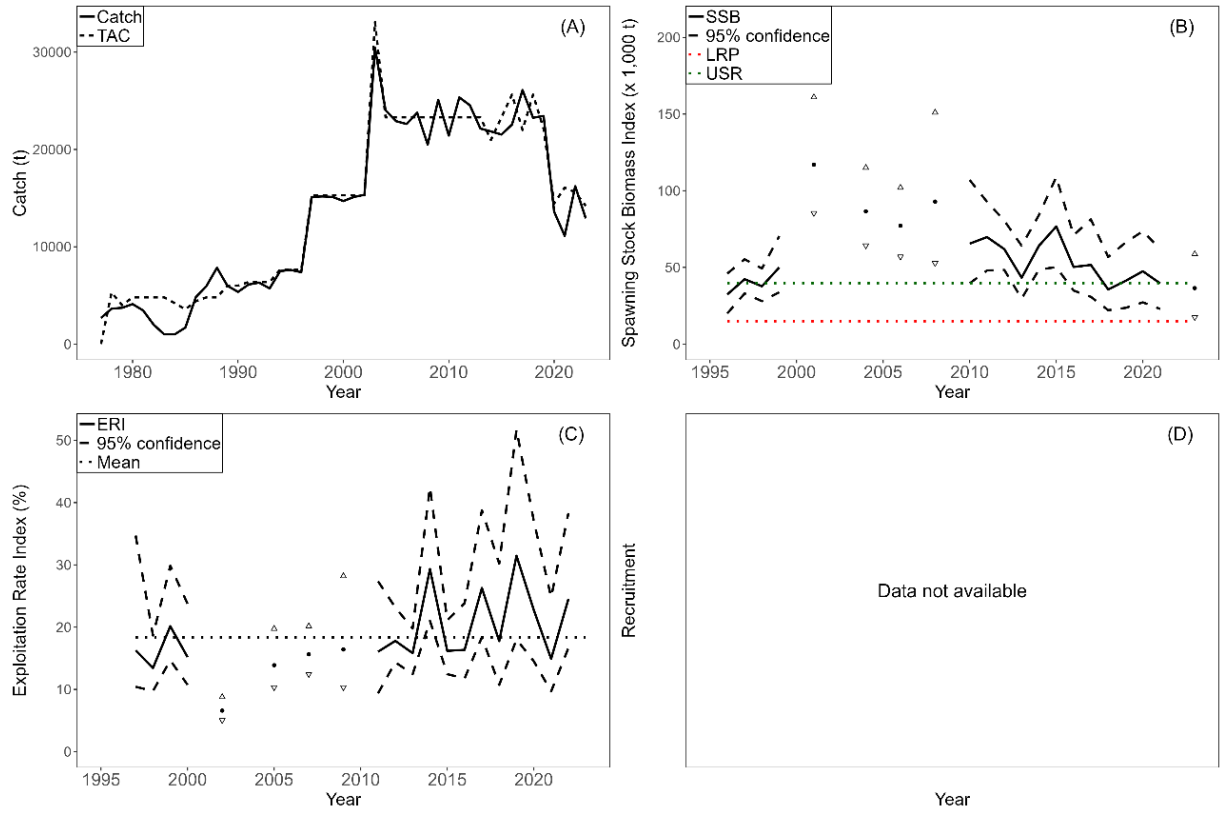


*Figure 3. Northern Shrimp in SFA 5. (A) Catch (t) and Total Allowable Catch (t) (Data for 2022/23–2023/24 are incomplete), (B) Spawning Stock Biomass Index (SSB, x 1,000 t) in relation to the Limit Reference Point (LRP; 14,900 t) and Upper Stock Reference (USR; 39,700 t), (C) Exploitation rate index (%), (D) Recruitment could not be estimated for this stock. On panel B and C, disconnected series points represent years during which the DFO fall multi-species survey did not sample NAFO Division 2H.*

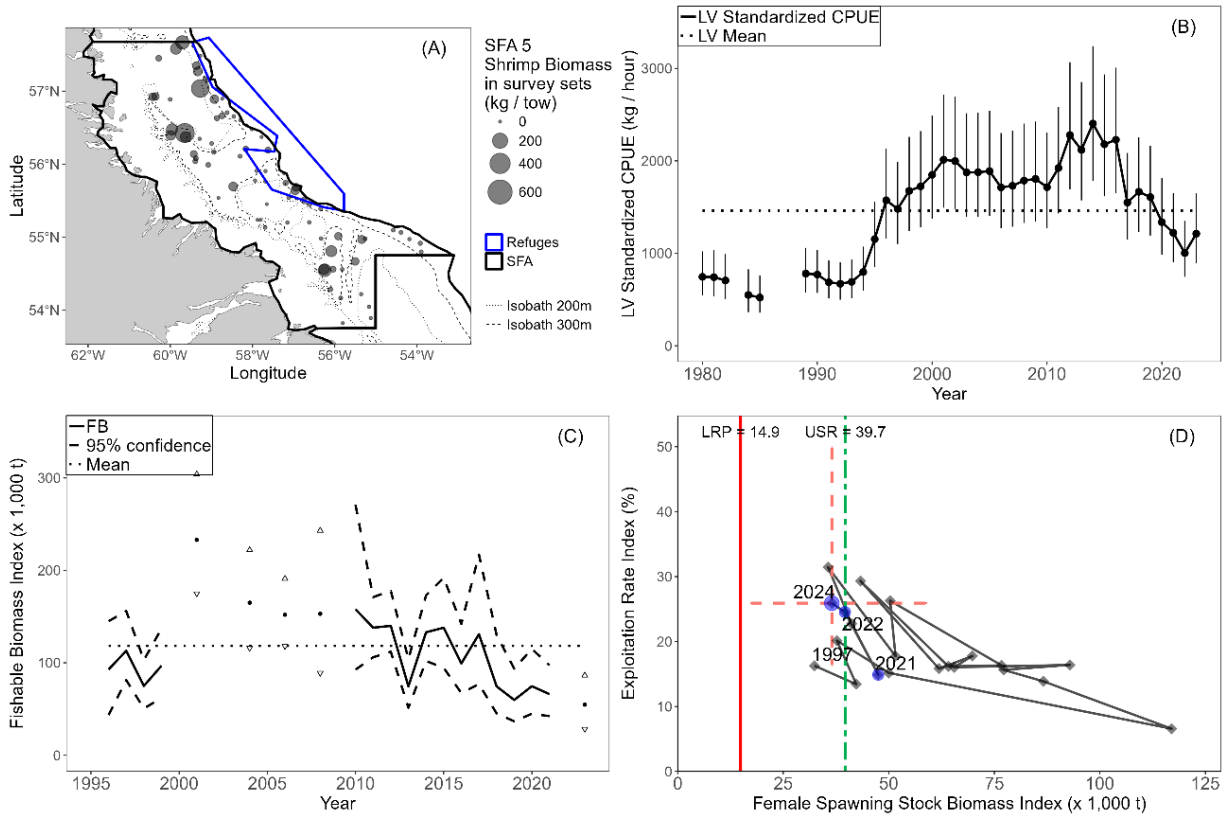


*Figure 4. Northern Shrimp in SFA 5. (A) Map of the survey northern shrimp catch in 2023 (kg / tow), (B) Standardized large-vessel CPUE (kg / hour), (C) Fishable Biomass Index (x 1,000 t), (D) IFMP PA Framework with ERI (%) versus female SSB index (x 1,000 t). On panel C, disconnected series points represent years during which the DFO fall multi-species survey did not sample SFA 5. On panel D, data point labels denote management year; the last three years (no point in 2023 due to the absence of survey in 2022) are represented with blue dots and the red cross indicates 95% confidence intervals for the fall 2023 female SSB index (horizontal line) and the projected 2024/25 ERI (vertical line).*

### Fishery

Total catch in 2023/24 was 12,911 t, 91% of the 14,200 t TAC (preliminary AQMS data as of February 9, 2024) (Figure 3a). The TAC of 14,200 t in 2022/23 (114% taken) was maintained for 2023/24.

Standardized large vessel CPUE declined from a historic high in 2014/15 to reach its lowest value in two decades by 2022/23. It has increased in 2023/24 but remained below the long-term mean (Figure 4b).

### Biomass

The SSB has dropped below the USR in 2023 with a 60% probability (Figure 3b). FB and female SSB indices declined compared to 2021 (no survey in 2022), by 17% (to 54,800 t; range 95% CI: 28,300 to 86,500 t) and 8% (to 36,500 t; range 95 % CI: 17,300 to 58,700 t) respectively, and were amongst the lowest levels in the survey time series (Figure 3b and 4c).

Similar to most survey years, in 2023, the highest concentrations of Northern Shrimp catch in SFA 5 were found in localized areas (channels) below-200 m (39%) and 201–300 m strata (32%) (Figure 4a).

### Exploitation

The ERI ranged between 6.6% and 31.5% from 1997 to 2022/23 (Figure 3c) and was not measurable for 2023/24 as there was no 2022 survey to allow the calculation of fishable biomass.

### Current Outlook

In 2023, the SFA 5 Northern Shrimp SSB dropped below the USR (with a 60% probability), but was above the LRP (with a 99% probability), placing the stock in the Cautious Zone.

## Historical and Recent Stock Trajectory and Trends – SFA 6 *P. borealis*

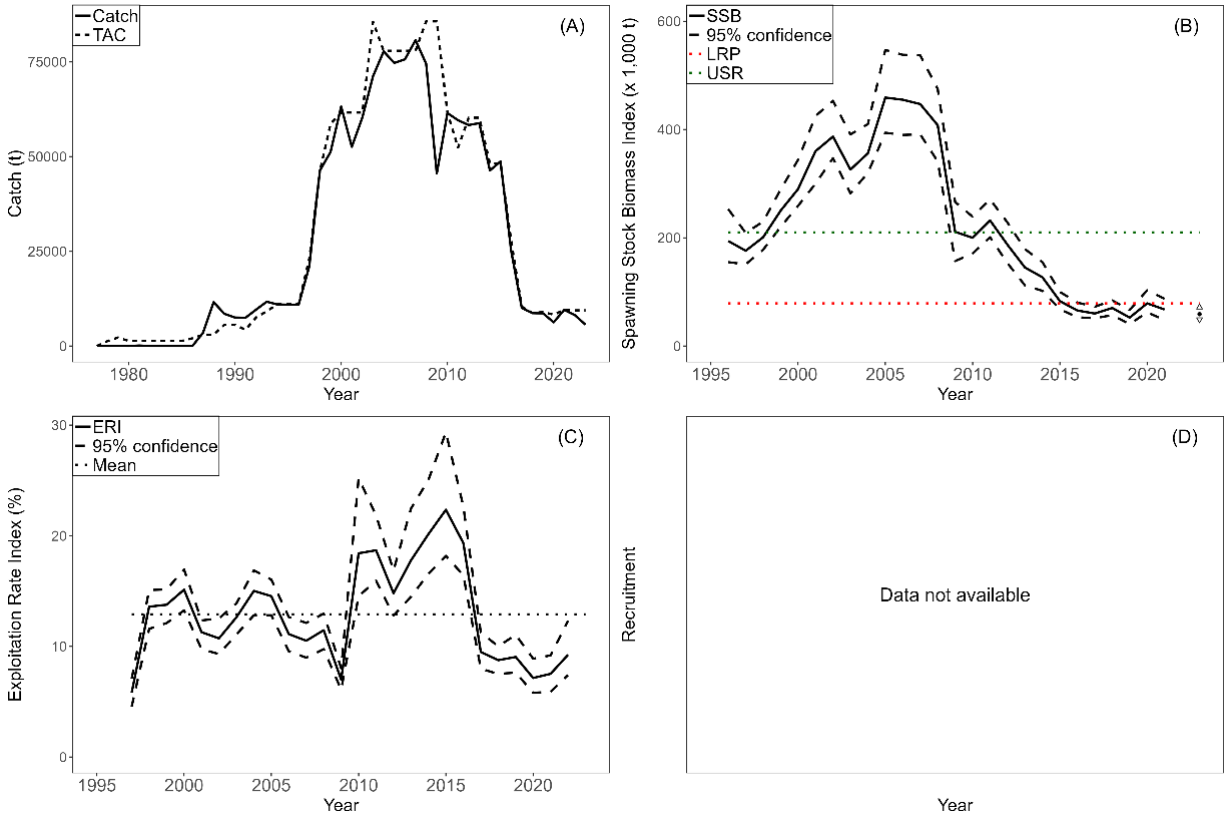


*Figure 5. Northern Shrimp in SFA 6. (A) Catch (t) and Total Allowable Catch (t) (Data for 2022/23–2023/24 are incomplete), (B) Spawning Stock Biomass Index (SSB, x 1,000 t) in relation to the Limit Reference Point (LRP; 78,800 t) and Upper Stock Reference (USR; 210,000 t), (C) Exploitation rate index (%), (D) Recruitment could not be estimated for this stock. On panel B, the disconnected series points represent data for 2023, as there was no DFO fall multi-species survey conducted in 2022 in SFA 6.*

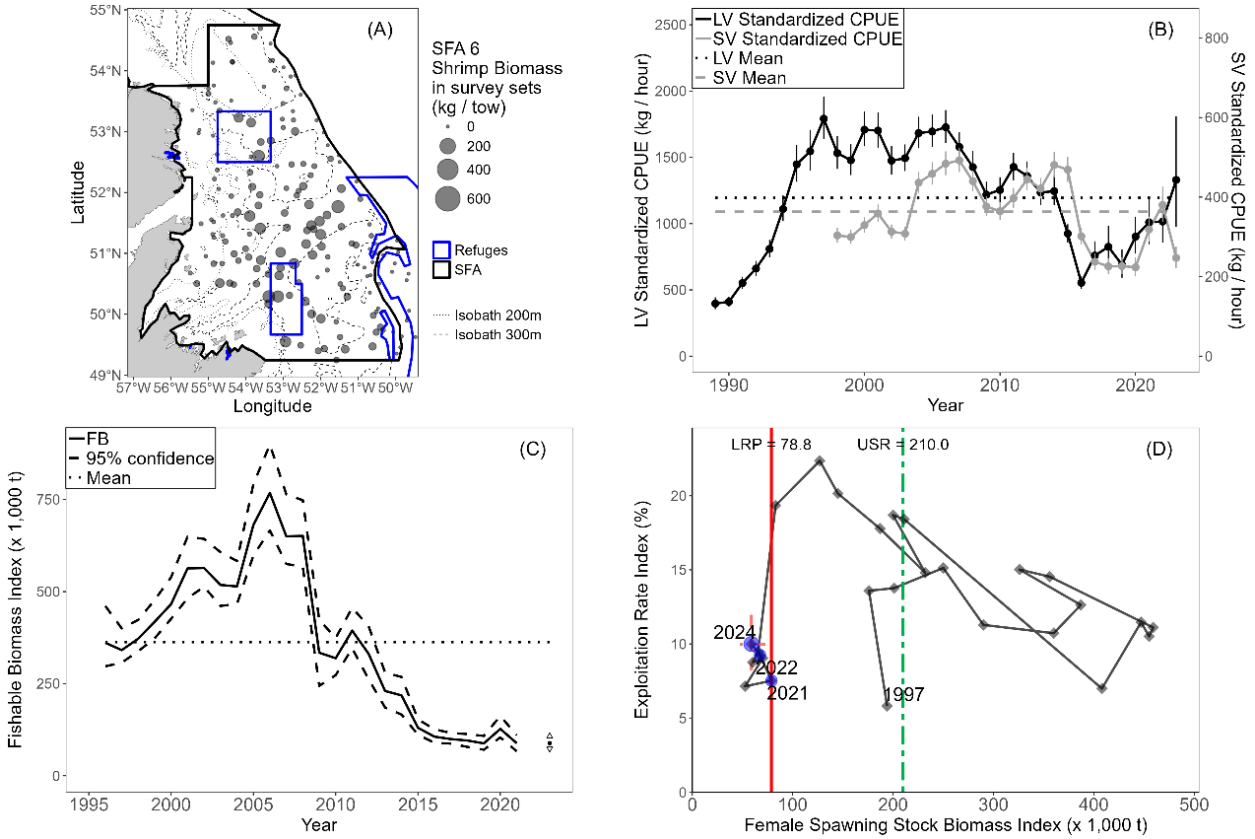


*Figure 6. Northern Shrimp in SFA 6. (A) Map of the survey Northern Shrimp catch in 2023 (kg / tow), (B) Standardized large (LV) and small vessels (SV) CPUE (kg / hour), (C) Fishable Biomass Index (x 1,000 t), (D) IFMP PA Framework with ERI (%) versus female SSB index (x 1,000 t). On panel C, the disconnected series points represent data for 2023, as there was no DFO fall multi-species survey conducted in 2022 in SFA 6. On panel D, data point labels denote management year; the last three years (no point in 2023 due to the absence of survey in 2022) are represented with blue dots and the red cross indicates 95% confidence intervals for the fall 2023 female SSB index (horizontal line) and the projected 2024/25 ERI (vertical line).*

### Fishery

Total catch in 2023/24 was 5,632 t, 60% of the 9,430 t TAC (preliminary AQMS data as of February 9, 2024) (Figure 5a). The TAC of 9,430 t in 2022/23 (86% taken) was maintained for 2023/24.

Since 2016/17, standardized small vessel CPUE has, with the exception of 2022/23, remained below the long-term mean (Figure 6b). Standardized large vessel CPUE has been on an increasing trend since 2016/17 and increased above the long-term mean in 2023/24.

### Biomass

FB and female SSB indices have remained amongst the lowest levels in the survey time series since 2016 (Figure 5b). Since 2021, the FB index has remained stable (at 88,200 t; range 95% CI: 73,700 to 106,000 t), but the SSB index has decreased by 13% (to 58,900 t; range 95 % CI: 49,200 to 71,300 t). The SSB index in 2023 was the 2nd lowest observed value in the time series. Similar to most years, in 2023, the highest concentrations of Northern Shrimp catch in

SFA 6 were found in areas within the 201–300 m (32%) and 301–400 m strata (46%) (Figure 6a).

### Exploitation

The ERI has ranged between 5.8% and 22.3% from 1997 to 2022/23 (Figure 5c) and was not measurable for 2023/24 as there was no 2022 survey to allow the calculation of fishable biomass. The rebuilding plan states a maximum value for the ERI of 10% while the stock is in the Critical Zone.

### Current Outlook

In 2023, the SFA 6 Northern Shrimp SSB was below the LRP with a greater than 99% probability, placing the stock in the Critical Zone.

## History of Catch and TAC

*Table 4. Nominal reported catches and TACs (t) for* Northern Shrimp *in SFA 4, 5, and 6 over the last 10 years. Catch are based on AQMS as of February 9, 2024. Catches for 2022/23 and 2023/24 are considered preliminary.*

| Year | SFA 4 | | SFA 5 | | SFA 6 | |
|---|---|---|---|---|---|---|
| | ***Catch (t)*** | ***TAC (t)*** | ***Catch (t)*** | ***TAC (t)*** | ***Catch (t)*** | ***TAC (t)*** |
| 2014/15 | 14,958 | 14,971 | 21,850 | 20,970 | 46,340 | 48,196 |
| 2015/16 | 15,050 | 14,971 | 21,530 | 23,300 | 48,722 | 48,196 |
| 2016/17 | 14,377 | 14,971 | 22,552 | 25,630 | 25,143 | 27,825 |
| 2017/18 | 16,439 | 15,725 | 26,102 | 22,000 | 10,065 | 10,400 |
| 2018/19 | 15,697 | 15,725 | 23,257 | 25,630 | 8,702 | 8,730 |
| 2019/20 | 11,232 | 10,845 | 23,440 | 22,100 | 8,638 | 8,961 |
| 2020/21 | 8,280 | 8,658 | 13,596 | 14,450 | 6,267 | 8,290 |
| 2021/22 | 10,272 | 9,957 | 11,129 | 16,080 | 9,554 | 9,534 |
| 2022/23 | 11,246 | 12,944 | 16,222 | 14,200 | 8,154 | 9,430 |
| 2023/24 | 8,759 | 14,886 | 12,911 | 14,200 | 5,632 | 9,430 |

## Projections

Projections or simulations have not been developed for this assessment as it is index-based.

## Ecosystem and Climate Change Considerations

The NL ocean climate varies on near-decadal time scales with known impacts on the ecosystem productivity. The NL bioregion experienced a cooler climate in the mid-2010s (~2014–17), followed by a warming phase that has been ongoing since about 2018 (including the warmest year on record in 2021). This ongoing warm phase likely contributed to the improved conditions observed at the lower trophic levels. These include earlier phytoplankton blooms, increased concentrations of nutrient and chlorophyll-*a*, higher abundance of *Calanus finmarchicus*, and near-to-above normal zooplankton biomass.

The NL bioregion underwent a regime shift in the early-1990s involving the collapse of the groundfish community and increases in shellfish, but these increases did not compensate for the loss of groundfish. NL ecosystems continue experiencing overall low productivity conditions, likely driven by bottom-up processes (e.g., food limitation) with total biomass well below

pre-collapse levels. Ecosystem trends in recent years (e.g., biomass trends, stomach content weights) indicate improvements from the lows in the late-2010s, but overall biomass has yet to reach the early-2010s level. Both 2H (SFA 5-north) and 2J3KL (SFA 5-south and SFA 6) have returned to a groundfish dominated community structure, from the shellfish dominated one that characterized these regions in the years after the ecosystem collapse. This transition started in the south and occurred a few years later in the north.

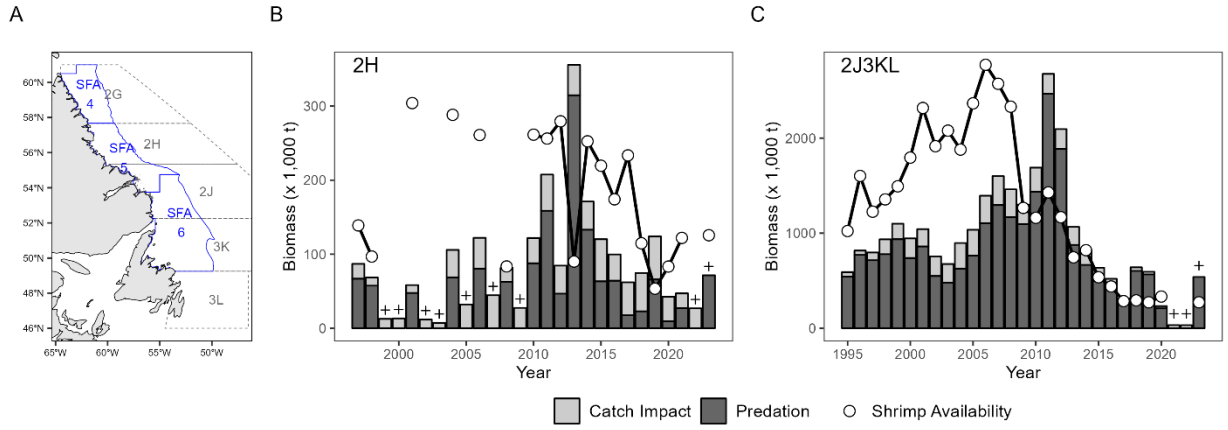


*Figure 7. Evaluation of the potential impacts of predation and fishing in relation to shrimp availability. (A) Map of NAFO divisions (grey), which is the geographic scale used in this ecosystem analysis, and SFAs (blue). (B) and (C) Estimated magnitudes of Predation and Potential Catch Impacts vs estimated Shrimp Availability in NAFO Divs. 2H and 2J3KL, respectively. Periods where Shrimp Availability (white points) is much greater than Predation plus potential Catch Impacts (light grey) indicate a potentially large scope for growth in the shrimp stock (i.e., potentially large shrimp surplus production), while periods where Shrimp Availability is of similar magnitude to Predation plus potential Catch Impacts indicate little scope for growth of the shrimp stock. The "+" marker indicates that either Predation or Catch Impact estimates are missing that year.*

While shrimp remains an important forage species, especially in the northern areas (~SFA 4–5), its dominance in the diet has decreased in recent years. Despite this signal, the predation mortality index on shrimp remains at a high level in 2J3KL (~SFA 6–7), in the south, but is four times lower in 2H (~SFA 5), and much lower in SFA 4, in the north.

Both fishing and predation have been potential drivers of the stock in 2H (~SFA 5), while predation has been the stronger potential stock driver in 2J3KL (~SFA 6–7) (Figure 7).

The trend in shrimp per capita net production in 2J3KL (~SFA 6–7) is likely associated with impacts from predation, fishing, and ocean climate. Since the late-2010s, per capita net production has been relatively stable at low levels, and no major changes are expected within the next 1–3 years based on these associations.

## OTHER MANAGEMENT QUESTIONS

Based on the recommendations from the July 2023 Comparative Fishing CSAS peer review meeting (DFO 2024b), conversion factors were applied to calibrate DFO trawl survey catches for Northern Shrimp across the DFO multi-species survey area (SFAs 5 and 6), taking into account the differences in catchability between outgoing and new vessels. Since outgoing vessels exhibited varying catchability compared to the new vessels, the historical survey time series (henceforth referred to as the unconverted time series) was adjusted to match the

characteristics of the newer vessels (hereafter referred to as the new vessel time series) by applying vessel and area specific conversions. Conversion factors were applied to the *CCGS Teleost* (hereafter, *Teleost*) and *CCGS Alfred Needler/Wilfred Templeman (*hereafter*, Needler/Templeman*) Northern Shrimp fall survey data, covering the historical survey period from 1996 to 2023. This adjustment brought the data into units equivalent to those of the new *CCGS* research vessels. Specifically, conversion factors were applied to the data collected by the *Teleost* in Div. 2HJ3KL and the *Needler/Templeman* in Div. 3KL, as per the recommendations. Additional analyses presented during the assessment showed consistency in environmental conditions (such as depth and temperature) and biological conditions (including the size distribution of shrimp caught) between the *Needler/Templeman* historical survey sets in Div. 2HJ, *Needler* sets from the comparative fishing program in 3KL, and *Teleost* historical sets in Div. 2HJ over the 2017–21 period. Based on these findings, the conversion factors originally intended for the *Needler/Templeman* in Div. 3KL were also applied in Div. 2HJ.

Using these converted data, the values of biomass indices, ERI, and reference points in SFAs 5 and 6 were recalculated for use in 2023 and going forward, using the same approach as in previous assessments. The absolute values of these recalculated indices are not directly comparable with the numbers reported in previous assessments. There is no known significant impact on the interpretation of stock status as reference points and biomass estimates were both recalculated in an equivalent manner. The biomass indices from the new vessels time series (1996–2021) show very similar trends but different values than the ones from the unconverted time series (i.e., reported in past assessments) because, for most shrimp sizes, the new vessels have a different shrimp catchability (DFO 2024b). Biomass indices serve as relative measures of stock size, and the reductions observed in the rescaling of the biomass indices does not indicate a decrease in shrimp abundance in the environment during the corresponding period. Instead, these differences reflect variations in survey catchability associated with the new vessels. Below is a summary outlining the consequences associated with the conversion of the historical time series to the equivalent of new vessels:

- In SFA 5, the median changes in the biomass indices were -7.4% for the SSB (range: -7.5–17.1%; Figure 8a) and -7.1% for the FB (range: -7.4–18.9%; Figure 8c).
- In SFA 6, the median changes in the biomass indices were -1.3% for the SSB (range: -7.6–20.4%; Figure 8b) and -1.0% for the FB (range: -6.6–21.7%; Figure 8d).

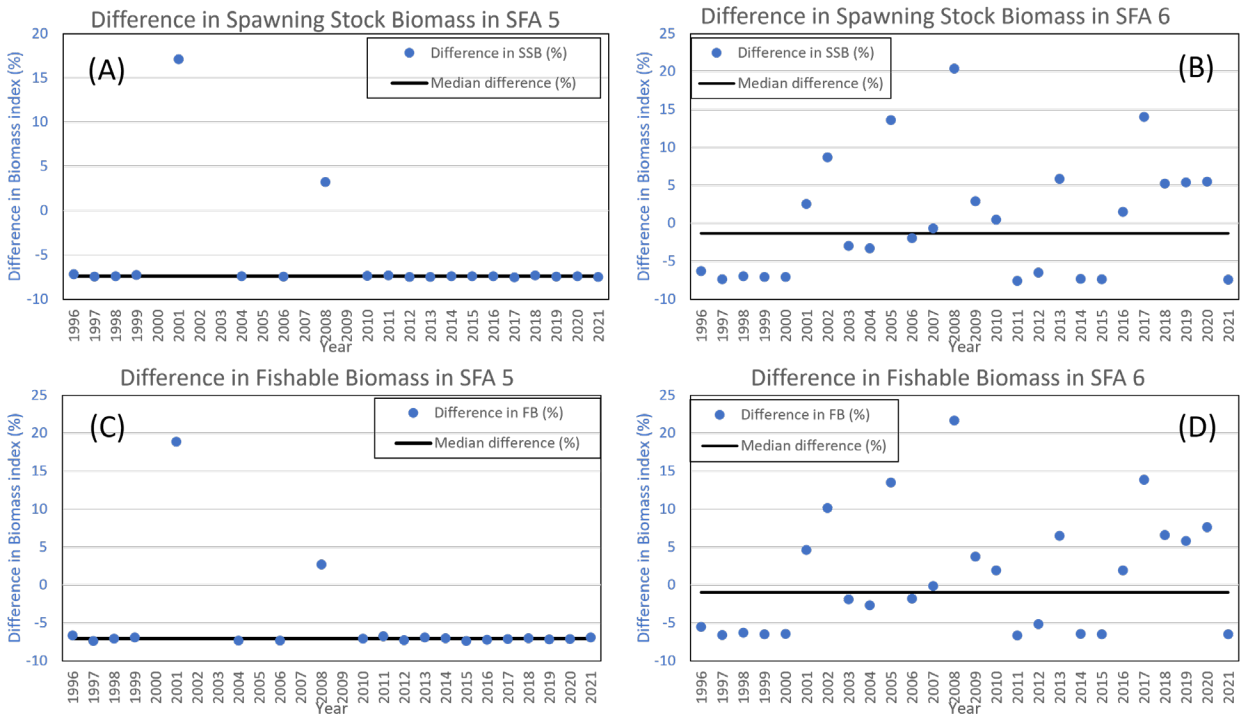


*Figure 8. Differences in biomass indices (%) between the old vessels and new vessels time series (1996–2021) in SFAs 5 and 6. Percentage difference for (A) SSB in SFA 5, (B) SSB in SFA 6, (C) FB in SFA 5, and (D) FB in SFA 6 are shown. Reported values (blue dots) represent the percentage difference for each survey year between the unconverted time series (i.e., reported in past assessments) and the new vessel time series. Positive (negative) values indicate years in which biomass indices from the new vessel time series are higher (lower) than those of the unconverted time series. The horizontal black lines represent the median difference for each of the biomass indices/SFA over the time series (1996–2021).*

The conversion of the FB time series from 1996–2021 has resulted in slightly different ERI estimates over the corresponding management periods (1997–2022/23). The median changes in ERI values were +1.14 percentage points in SFA 5 and +0.02 percentage points in SFA 6 when compared to estimates calculated using the unconverted time series. Harvest Decision Rules for these stocks are directly calculated from FB indices. Without corrections, applying a given exploitation rate to the new vessels FB indices would result in a lower TAC compared to applying the same exploitation rate to the unconverted time series FB indices.

## SOURCES OF UNCERTAINTY

In 2023, the NSRF survey faced a challenge as primary trawl sensor data were missing for 2/3 of the trawls. Bottom contact time was estimated for these trawls, including those in SFA 4, using a regression between CTD data (Conductivity, Temperature, Depth) and primary trawl sensor data, where available. Despite this deviation from the usual method, it is not anticipated to affect the assessment outcome.

The relative catchabilities for the four research vessels (*Cape Ballard, Aqviq, Kinguk,* and *Katsheshuk II*) that have been used throughout the time series in SFA 4 have not been empirically tested, and thus the relative catchability between the vessels is unknown.

The conversion factors in the DFO multi-species fall survey for Northern Shrimp data included uncertainty estimates, which were not considered in the current assessment. Expanding Div. 3KL Northern Shrimp conversion factors for the *Needler/Templeman* survey sets to adjacent Div. 2HJ introduced slight additional uncertainties to biomass estimates, but they're expected to minimally impact the assessment outcome.

The female SSB pertinent to a specific management area includes animals whose offspring may not be harvested there, regardless of where they spawn. Strong currents, especially affecting shrimp larvae, present challenges in estimating female SSB in SFA 4–6. Therefore, changes in one SFA can affect others.

The variability of Northern Shrimp's vertical distribution within or among years and across different locations is unclear. Biomass estimates rely on bottom trawl surveys, which may miss shrimp away from the seafloor, influencing observed fluctuations rather than population size.

The trawls used in the survey have a catchability coefficient below one, making them an index of biomass rather than a precise measure. The total fishery-induced mortality, encompassing both landed catch and incidental trawling deaths, is unknown, resulting in exploitation rates being relative rather than absolute.

Exploitation rates vary greatly across fisheries, regions, and time, introducing uncertainty when using commercial catch rates to gauge stock status. Factors like ice cover, bycatch, and market conditions impact commercial effort, while changes in fishing practices can unpredictably affect CPUE.

Existing data (catch rates, and limited surveys in combination with stomach content analyses) indicate that Northern Shrimp biomass in SFA 5 and 6 was considerably lower in the late-1980s and early-1990s, compared to the start of the research vessel time series (Pedersen et al. 2022). Incorporating and accurately estimating these historical shrimp biomass levels remains a research challenge.

## Research Recommendations

- Continue exploring the relationship between environmental and ecological factors, including ice cover, ocean currents, predation, and larval transport, and their impacts on shrimp population dynamics. This investigation aims to integrate these findings into a forthcoming assessment model for Northern Shrimp.
- Continue ongoing studies (Marine Institute and NSRF) on shrimp diet and predation (adults and larvae) to integrate these findings into the assessment.
- Investigate small vessel CPUE in SFA 4 and SFA 5 and consider including this data in future analyses.
- Investigate the relative catchabilities of the four fishing vessels in SFA 4.
- Investigate how to accurately estimate historical shrimp biomass levels and incorporate longer time-series data into future research.

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