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Newfoundland and Labrador Region
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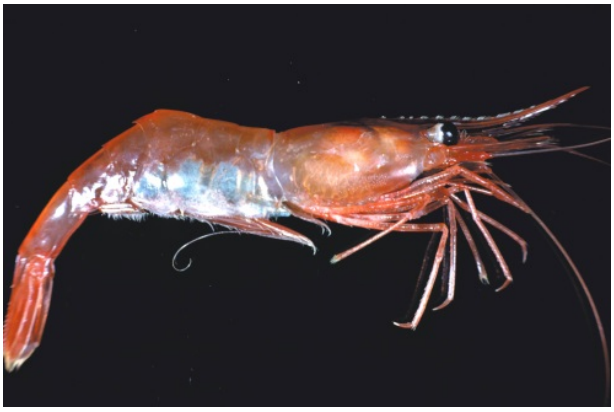
Canadian Science Advisory Secretariat
Science Advisory Report 2026/033

DEVELOPMENT OF A PRECAUTIONARY APPROACH FRAMEWORK FOR NORTHERN SHRIMP (*PANDALUS BOREALIS*) IN SHRIMP FISHING AREAS 4–7, EASTERN ASSESSMENT ZONE, AND WESTERN ASSESSMENT ZONE



*Northern Shrimp (*Pandalus borealis*; Fisheries and Oceans Canada [DFO]).*

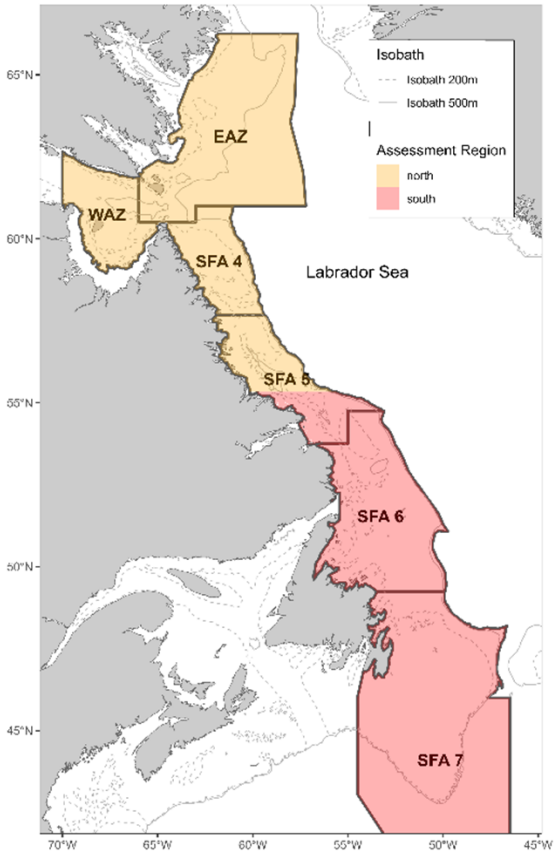


Figure 1. Map showing six current shrimp fishing areas (SFAs) (Eastern Assessment Zone [EAZ], Western Assessment Zone [WAZ], SFAs 4–7) and two new stock assessment regions (north and south) used in the assessment framework.

CONTEXT

It is recognized that Northern Shrimp (*Pandalus borealis*) are distributed broadly over the Northwest Atlantic Ocean, including Shrimp Fishing Areas (SFAs) 4–7, Eastern Assessment

Zone (EAZ) and Western Assessment Zone (WAZ), and that these areas are connected through larval dispersal. For each SFA and assessment zone, stock advice has been based on qualitative evaluations of biomass indices in relation to historical levels and provided in the context of the Precautionary Approach (PA) Framework. However, the biological population is recognized to be distributed over a larger region than the management scale. A population model is needed to align the assessment with the biological population and incorporate environmental and ecosystem understanding into the assessment. Development of a population assessment model for Northern Shrimp facilitates quantitative risk-based science advice, allowing fisheries managers to consider projected changes in stock abundance and yield under alternative management measures considered in the decision-making process. A population assessment model and revised limit reference points (LRPs) also inform future work to update the PA Frameworks in place for Northern Shrimp in SFAs 4–7, EAZ, and WAZ, including harvest decision rules and upper stock reference points (USRs).

For this reason, a multi-regional (Arctic and Newfoundland & Labrador regions) PA Framework meeting was required to peer-review a population model for Northern Shrimp, incorporating information from the species' broader geographic range within current management areas of the EAZ, WAZ, and SFAs 4–7.

This Science Advisory Report is from the multi-regional peer review of December 9–13, 2024, on the Development of a Precautionary Approach Framework for Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 4–7, Eastern Assessment Zone, and Western Assessment Zone. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- A new understanding of Northern Shrimp population structure, based upon their distribution, dispersal, and life history traits, was adopted. Therefore, the spatial scale of assessment for Northern Shrimp has changed from six to two stock assessment regions (SAR) - North (NSAR) and South (SSAR) - divided by the boundary between Northwest Atlantic Fisheries Organization (NAFO) Divisions 2H and 2J.
- A Bayesian size-structured stock assessment modeling framework was adopted that incorporates fishery and biomass indices from spatiotemporal modeling and size composition to estimate trends in Northern Shrimp biomass, recruitment, natural mortality rates, and exploitation rates for each stock assessment region.
- Model results highlight groundfish predation as an important driver of Northern Shrimp natural mortality in the SSAR, but the role of predation as a driver of population dynamics in the NSAR is unclear. Predation effects are currently represented in the model via time-varying natural mortality.
- A biomass at maximum sustainable yield (B_{msy}) proxy value for each stock assessment region was calculated as 40% of unfished biomass (i.e., B_{msy}-proxy = B_0 x 0.4).
- A Limit Reference Point (LRP) for each stock assessment region was adopted as 0.5 x B_{msy}-proxy.
- An Upper Stock Reference point (USR) of 80% of the B_{msy}-proxy was recommended for each stock assessment region.
- Reference point calculations reflect estimated natural mortality and sex-transition rates from the most recent eight years (i.e., approximately one Northern Shrimp generation).

INTRODUCTION

Northern Shrimp (*Pandalus borealis*) are distributed broadly over the Northwest Atlantic Ocean, including Shrimp Fishing Areas (SFAs; Figure 1) 4–7, the Eastern Assessment Zone (EAZ) and the Western Assessment Zone (WAZ), and these areas are connected through larval dispersal. For each SFA and assessment zone, stock advice has historically been based on qualitative evaluations of biomass indices in relation to historic levels and provided in the context of the Precautionary Approach (PA) Framework (DFO 2024a, 2024b, 2024c, NAFO 2024). However, the biological population is recognized to be larger than the management scale (Baker et al. 2025). To align the assessment with the biological population and facilitate incorporation of environmental and ecosystem variables into the assessment, a population model is needed. Development of a stock assessment model for Northern Shrimp will facilitate provision of risk-based science advice, allowing fisheries managers to consider projected changes in stock abundance and the potential impacts of various management measures in the decision-making process.

For this reason, a multi-regional (DFO's Arctic and Newfoundland & Labrador Regions) PA Framework meeting was held to peer-review a population model for Northern Shrimp that encompasses the current management areas of the EAZ, WAZ, and SFAs 4–7, and incorporates information from the species' broader geographic range.

ANALYSIS

New stock structure

Northern Shrimp has been managed as a series of separate stocks with the general assumption that each stock is supported by local recruitment with an unknown level of connectivity between areas. The magnitude of movement or connectivity between areas was unquantified, but recognized as a significant source of uncertainty in stock assessments (e.g., DFO 2024a). Misalignment between the biological population and assessment and management processes creates unquantified uncertainty which increases the risk associated with management decisions.

To address this ongoing source of uncertainty, spatiotemporal models were used to identify patterns in stock structure, specifically patterns in population density, sex ratio, and female length (Baker et al. 2025). These results were combined with recent genomic and larval dispersal data to quantify Northern Shrimp population structure across SFAs 4–7, the EAZ and the WAZ. Two data clusters were identified throughout the time series, which separated Northern Shrimp into North and South stock assessment areas (NSAR and SSAR). The results were presented as a foundation for developing a new Northern Shrimp stock assessment framework for two stock assessment regions (NSAR and SSAR) to replace the current matrix of six assessment areas (SFAs 4–7, the EAZ and the WAZ). The two regions are divided by the line located at the boundary between Northwest Atlantic Fisheries Organization (NAFO) Divisions 2H and 2J.

Ecosystem Information

Northern Shrimp is a forage species that is consumed by Atlantic Cod (*Gadus morhua*), Greenland Halibut (*Reinhardtius hippoglossoides*), redfish (*Sebastes* spp.), and other fishes, birds, and marine mammals. Dramatic changes (regime shifts) in marine ecosystems and communities (Koen-Alonso and Cuff 2018) have altered predator-prey dynamics, with the Newfoundland and Labrador marine community changing from a groundfish-dominated

community to a shellfish-dominated community in the 1990s. Ecosystem productivity has also changed over time; the Northern Shrimp population, particularly in the SSAR, has recently been transitioning to having lower recruitment and/or higher mortality in response to changes in the ecosystem.

To incorporate the effects of predation into Northern Shrimp stock assessments, diet data from predators caught during DFO research vessel surveys, including Atlantic Cod and Greenland Halibut, were examined. Atlantic Cod and Greenland Halibut diet appeared to reliably track Northern Shrimp biomass, with Atlantic Cod showing a better fit.

New model

A new population model for Northern Shrimp was reviewed. The new population model incorporated information from the species' broader geographic range, adopting the NSAR and SSAR identified through recent spatiotemporal and genomic analyses (Baker et al. 2025) in place of the six current assessment areas (SFAs 4–7, EAZ, and WAZ). A size-structured population model was developed using the Spatially Integrated Statistical Catch at Length/Size (SISCALS) model. SISCALS computes growth, survival, and sex transition and other characteristics on a quarterly time step (i.e., four times per year). The effect of incorporating quarterly or annual sex transitions was explored but there was little difference in results between the two model configurations; therefore, sex transition only occurred once each year in the 4th quarter in the final model. Recruitment also occurred in a single quarter each year. Considering diet analysis results, predation effects were incorporated into the model by adding time-varying natural mortality.

The stock assessment model was designed to:

1. Estimate biomass, fishing mortality, natural mortality, growth, and recruitment for NSAR and SSAR, subject to the assumed structure for population dynamics and observation models;
2. Derive model-based reference points from alternative spawning potential ratio (SPR) options;
3. Establish Bayesian posterior probability distributions of current stock status with respect to SPR reference points;
4. Explore possible ecosystem drivers (e.g., predation, growth) of changes in productivity;
5. Establish a framework for testing harvest strategies and decision rules.

The model review included discussions of the relationship between model estimated biomass and biomass indices from surveys, shrimp growth, natural mortality, recruitment, larval dispersal, fishery-derived catch-per-unit-effort, and the male to female sex transition. Examining the model goodness of fit results, SISCALS successfully captured large-scale variations in stock biomass, particularly in the SSAR. Posterior plots of model parameters showed good model performance. The Atlantic Cod diet index was compared to model outcomes; the results overlapped fairly well, with evidence of a time lag in the trend residuals.

The SISCALS model estimated a high survey catchability in the NSAR, meaning that the spatiotemporal model survey index is potentially a positively biased estimate of shrimp abundance. This raised some concerns, as biased survey catchability could affect Science advice regarding harvest levels. After discussion, the conclusion was that the model interprets the trend in biomass in response to the catch and that catchability just scales the survey index to the underlying model biomass in order to compute the likelihood. The catch and survey trend, therefore, determine the productivity of the stock, not catchability. Therefore, overestimating

catchability would not affect the estimate of productivity. Nevertheless, there was also consensus to investigate the cause of the high catchability estimates as part of future research.

The model results were used to assess stock trends in each stock assessment region. Northern Shrimp biomass in the NSAR has been declining, the exploitation rate has been increasing, and fewer shrimp have been surviving to transition into females, which has reduced the spawning stock biomass. Biomass has also declined in the SSAR with a higher exploitation rate, low recent recruitment, and an increasing trend in natural mortality (although stable recently). In the SSAR, natural mortality was highly correlated with Atlantic Cod and redfish separately modelled biomass.

Reference points

Spawning Potential Ratio (SPR) was used to establish a B_{msy}-proxy and PA Framework reference points. Spawning Potential Ratio (SPR) represents the fraction of unfished spawning stock biomass (SSB) that is assumed to coincide with B_{msy}. A B_{msy}-proxy value for each SAR was calculated as 40% of unfished biomass (i.e., B_{msy}-proxy = $0.4B_0$). A LRP for each stock assessment region was adopted as $0.5B_{msy}$-proxy; in determining an appropriate level for the LRP there was notable consideration of the biological capacity for Northern Shrimp population growth, tempered by the importance of Northern Shrimp as a forage species that directly supports key predators (i.e., Atlantic Cod, Greenland Halibut, redfish, marine mammals, seabirds) and is important for overall ecosystem health. An USR point of 80% of the B_{msy}-proxy was recommended for each SAR. Reference point calculations reflect estimated natural mortality and sex-transition rates from the most recent eight years (Expected to be approximately one Northern Shrimp generation).

Sources of Uncertainty

- Immigration of recruits from areas adjacent to the NSAR (e.g., SFAs 0 and 1, inshore waters within the Nunavut Settlement Area, West Greenland). Inclusion of “drift” in the model considers movement of shrimp from the NSAR to the SSAR but presently there is no direct inclusion of external inputs to the NSAR.
- Length frequencies are not standardized via the same spatiotemporal model as survey biomass indices.
- Predation by Atlantic Cod, Greenland Halibut, and redfish was considered during model development but ultimately there was concern that inclusion of predation requires a better understanding of the form of the relationship between predation and mortality (i.e., linear or functional response). The effect of predation on mortality needs to be further examined and should expand to include consideration of predation by marine mammals, seabirds and other fish species (e.g., grenadiers).
- Shrimp growth and mortality rates in the NSAR.
- Need to determine at what population level serious harm occurs to the stock. Data at present do not allow an analytical determination. This information is needed to develop a more informed LRP.

CONCLUSION

- A new understanding of Northern Shrimp population structure, based upon their distribution, dispersal, and life history traits, was adopted. Therefore, the spatial scale of assessment for

Northern Shrimp has changed from six to two stock assessment regions – NSAR and SSAR - divided by the boundary between NAFO Divisions 2H and 2J.

- A Bayesian size-structured stock assessment modeling framework was adopted that incorporates fishery and biomass indices from spatiotemporal modeling and size composition to estimate trends in Northern Shrimp biomass, recruitment, natural mortality rates, and exploitation rates for each SAR.
- Model results highlight groundfish predation as an important driver of Northern Shrimp natural mortality in the SSAR, but the role of predation as a driver of population dynamics in the NSAR is unclear. Predation effects are currently represented in the model via time-varying natural mortality.
- A B_{msy}-proxy value for each stock assessment region was calculated as 40% of unfished biomass (i.e., B_{msy}-proxy = $0.4B_0$).
- A Limit Reference Point (LRP) for each stock assessment region was adopted as $0.5B_{msy}$-proxy.
- An Upper Stock Reference point (USR) of 80% of the B_{msy}-proxy was recommended for each stock assessment region.
- Reference point calculations reflect estimated natural mortality and sex-transition rates from the most recent eight years (i.e., approximately one Northern Shrimp generation).

Research Recommendations

- Standardize survey length-composition data using a spatiotemporal model to reduce potential for natural mortality and catchability bias.
- Further analysis should be done to understand the potential bias caused by partial survey coverage and explore potential “fixes” to address any historical periods with low survey coverage. This includes impacts of partial survey coverage on estimated catchability and sex-transition and growth model bias due to morphological differences for EAZ shrimp.
- Explore alternative sampling design for biomass and length composition data from both fisheries and surveys to optimize information content while minimizing bias.
- Investigate relationships between shrimp population dynamics (e.g., mortality, growth, productivity, density dependence) and environmental and ecological factors, including sea ice cover, ocean currents, predation, and larval transport with consideration given to differences between the two stock assessment regions.
- Improve understanding of the effect of predation on shrimp population dynamics and the integration of predation into future versions of SISCALS, both in terms of natural mortality to inform the model, but also on predators’ dependence on shrimp to inform LRP revisions. Analyses may include the integration of additional data using predator stomach contents and consideration of predation by marine mammals, seabirds and other fish species (e.g., grenadiers).

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SOURCES OF INFORMATION

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Aussi disponible en français :

*MPO. 2026. Élaboration d'un cadre de l'approche de précaution pour la crevette nordique (*Pandalus borealis*) dans les zones de pêche de la crevette 4 à 7, la zone d'évaluation est et la zone d'évaluation ouest. Secr. can. des avis sci. du MPO. Avis sci. 2026/033.*

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